EXHIBIT A

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United States Patent [19]

Henderson, Jr. et al.

[11] **Patent Number: 5,072,412**

[45] **Date of Patent: Dec. 10, 1991**

[54] **USER INTERFACE WITH MULTIPLE WORKSPACES FOR SHARING DISPLAY SYSTEM OBJECTS**

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[73] Assignee: **Xerox Corporation**, Stamford, Conn.

[21] Appl. No.: **30,766**

[22] Filed: **Mar. 25, 1987**

[51] **Int. Cl.**[5] **G06F 15/62**

[52] **U.S. Cl.** **395/159**; 395/158

[58] **Field of Search** 364/518–522; 340/724, 716; 382/44–46

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(List continued on next page.)

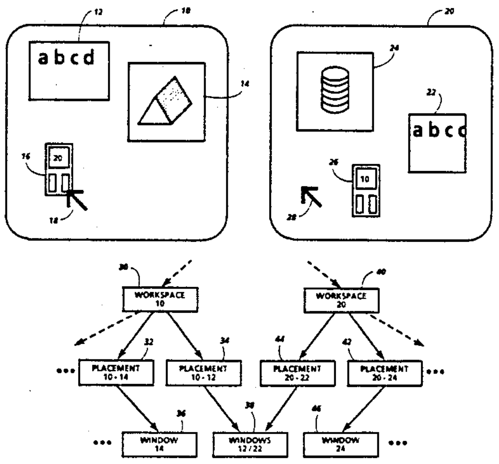
Primary Examiner—Heather R. Herndon

Attorney, Agent, or Firm—James T. Beran

[57] **ABSTRACT**

Workspaces provided by an object-based user interface appear to share windows and other display objects. Each workspace's data structure includes, for each window in that workspace, a linking data structure called a placement which links to the display system object which provides that window, which may be a display system object in a preexisting window system. The placement also contains display characteristics of the window when displayed in that workspace, such as position and size. Therefore, a display system object can be linked to several workspaces by a placement in each of the workspaces' data structures, and the window it provides to each of those workspaces can have unique display characteristics, yet appear to the user to be the same window or versions of the same window. As a result, the workspaces appear to be sharing a window. Workspaces can also appear to share a window if each workspace's data structure includes data linking to another workspace with a placement to the shared window. The user can invoke a switch between workspaces by selecting a display object called a door, and a back door to the previous workspace is created automatically so that the user is not trapped in a workspace. A display system object providing a window to a workspace being left remains active so that when that workspace is reentered, the window will have the same contents as when it disappeared. Also, the placements of a workspace are updated so that when the workspace is reentered its windows are organized the same as when the user left that workspace. The user can enter an overview display which shows a representation of each workspace and the windows it contains so that the user can navigate to any workspace from the overview.

62 Claims, 19 Drawing Sheets



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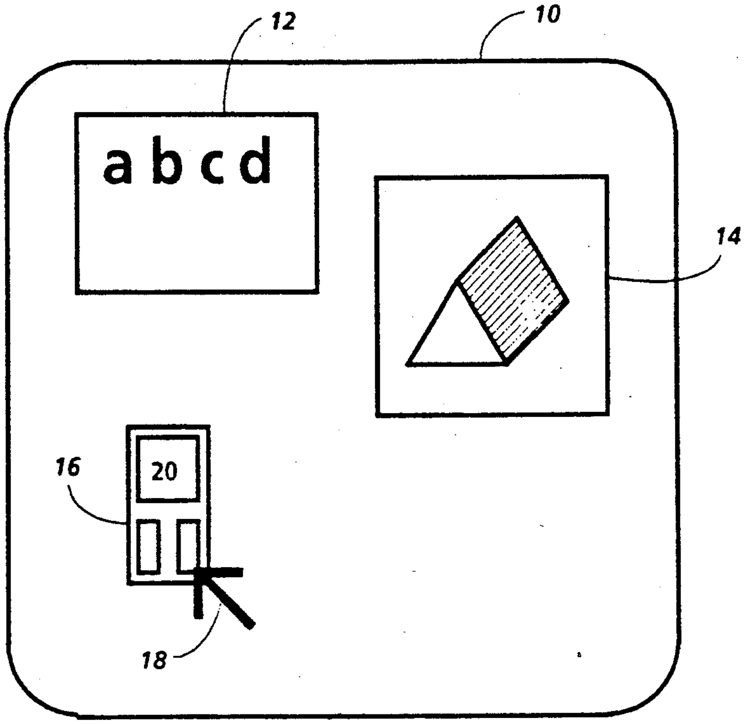

12
10
a b c d
14
16
20
18

FIG. 1A

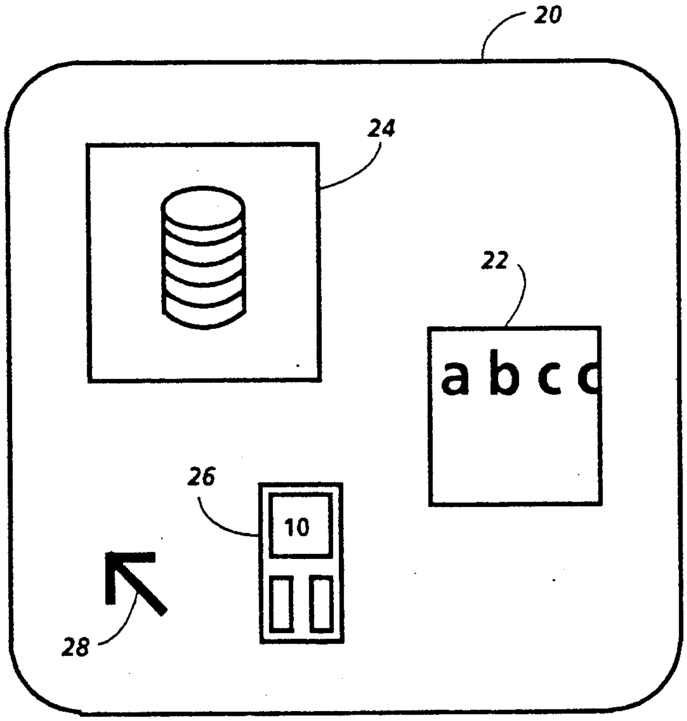

20
24
22
a b c
26
10
28

FIG. 1B

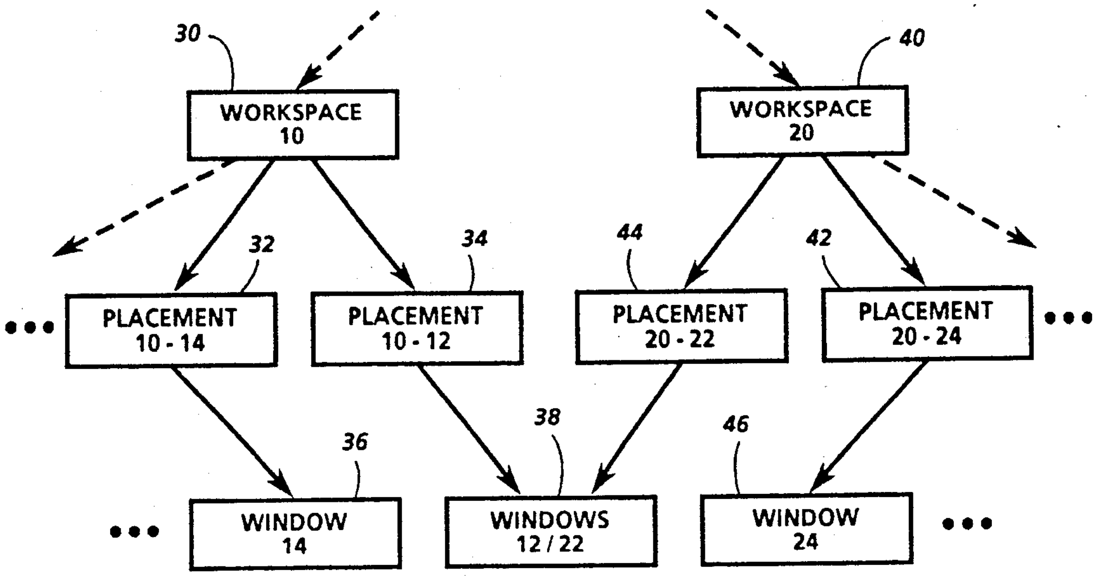

30
WORKSPACE 10
40
WORKSPACE 20
32
34
44
42
PLACEMENT 10 - 14
PLACEMENT 10 - 12
PLACEMENT 20 - 22
PLACEMENT 20 - 24
36
38
46
WINDOW 14
WINDOWS 12 / 22
WINDOW 24

FIG. 2

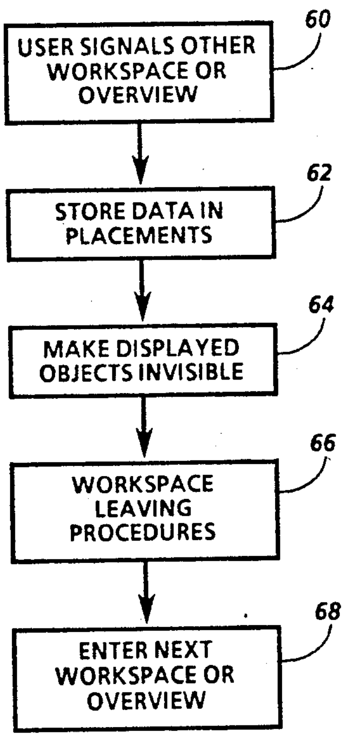

60
USER SIGNALS OTHER WORKSPACE OR OVERVIEW
62
STORE DATA IN PLACEMENTS
64
MAKE DISPLAYED OBJECTS INVISIBLE
66
WORKSPACE LEAVING PROCEDURES
68
ENTER NEXT WORKSPACE OR OVERVIEW

FIG. 3

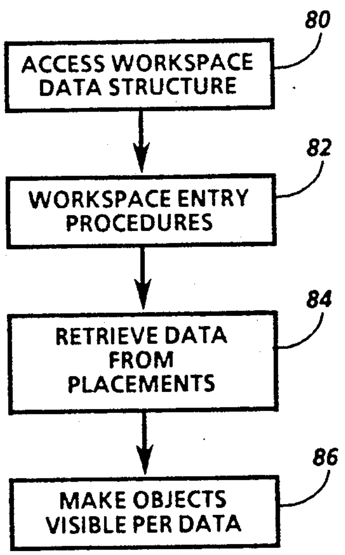
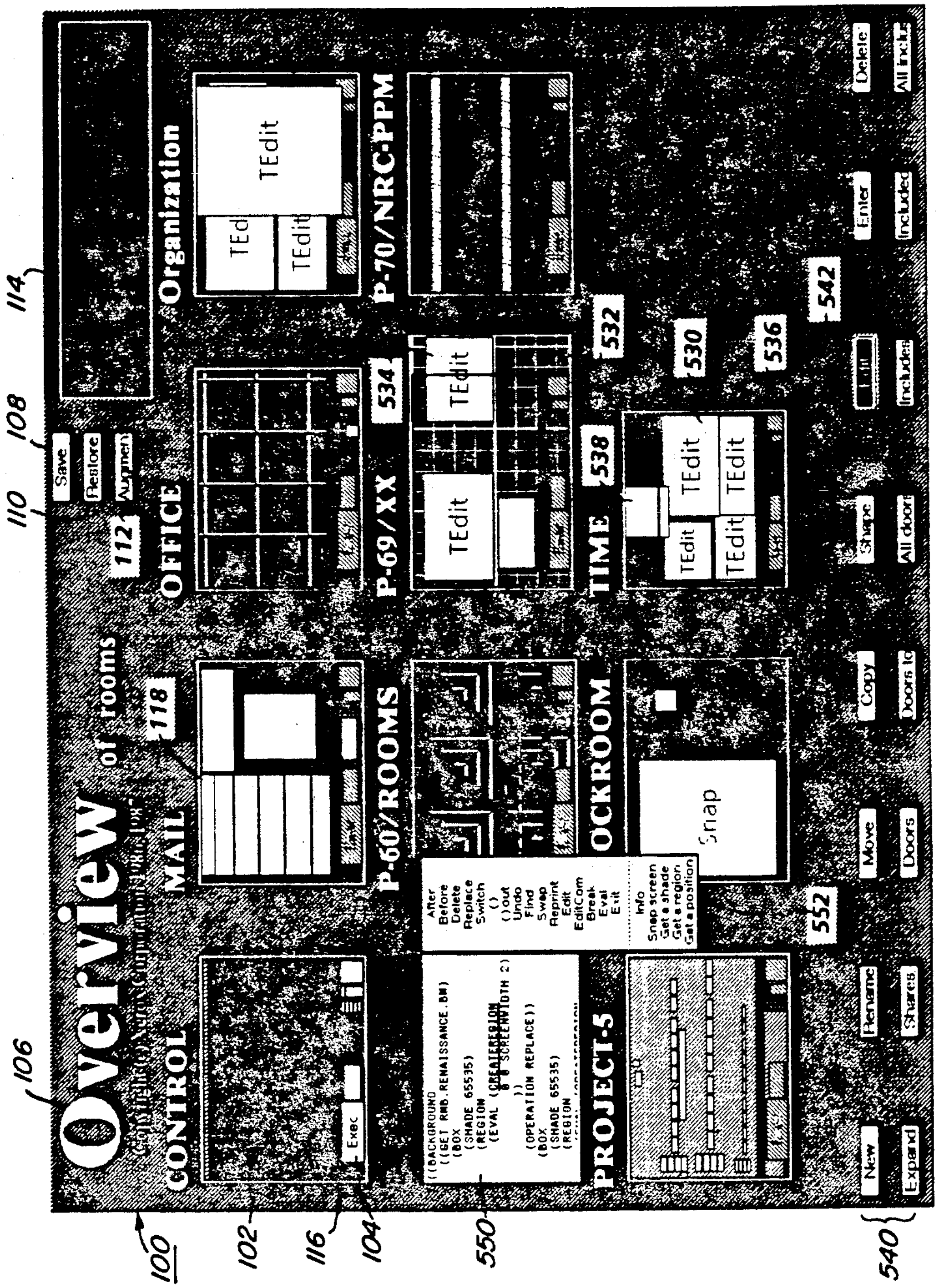

80
ACCESS WORKSPACE DATA STRUCTURE
82
WORKSPACE ENTRY PROCEDURES
84
RETRIEVE DATA FROM PLACEMENTS
86
MAKE OBJECTS VISIBLE PER DATA

FIG. 4

FIG. 5


Overview of rooms
CONTROL
MAIL
OFFICE
Organization
P-60/ROOMS
P-69/XX
P-70/NRC-PPM
PROJECT-5
TIME
Save
Restore
Exec
TEdit
Snap
New
Expand
Rename
Shares
Move
Doors
Copy
Shape
All doors
Enter
Included
Delete
100
102
104
106
108
110
112
114
116
118
530
532
534
536
538
540
542
550
552

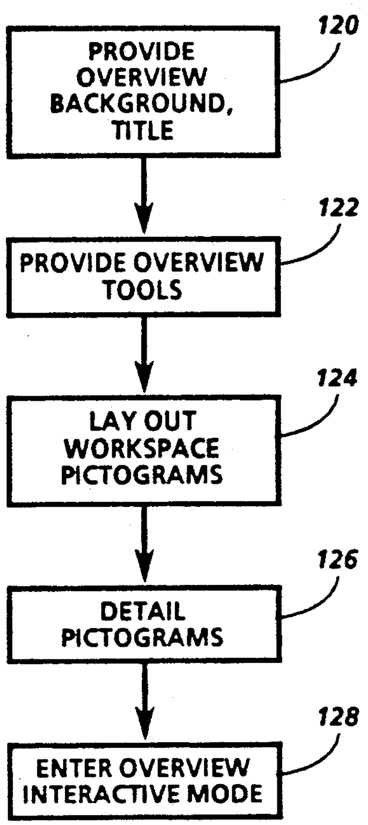

120
PROVIDE OVERVIEW BACKGROUND, TITLE
122
PROVIDE OVERVIEW TOOLS
124
LAY OUT WORKSPACE PICTOGRAMS
126
DETAIL PICTOGRAMS
128
ENTER OVERVIEW INTERACTIVE MODE

FIG. 6

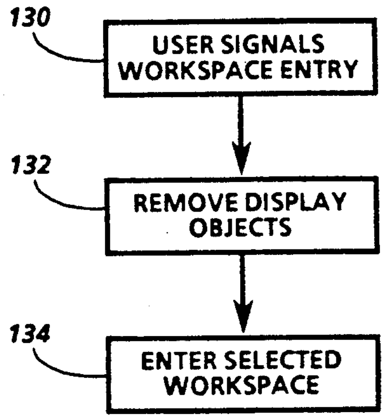

130
USER SIGNALS WORKSPACE ENTRY
132
REMOVE DISPLAY OBJECTS
134
ENTER SELECTED WORKSPACE

FIG. 7

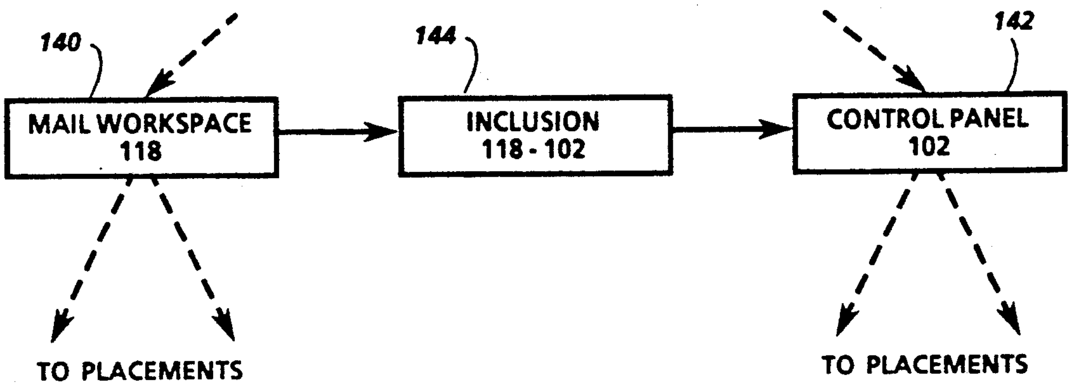

140
MAIL WORKSPACE 118
144
INCLUSION 118 - 102
142
CONTROL PANEL 102
TO PLACEMENTS
TO PLACEMENTS

FIG. 8

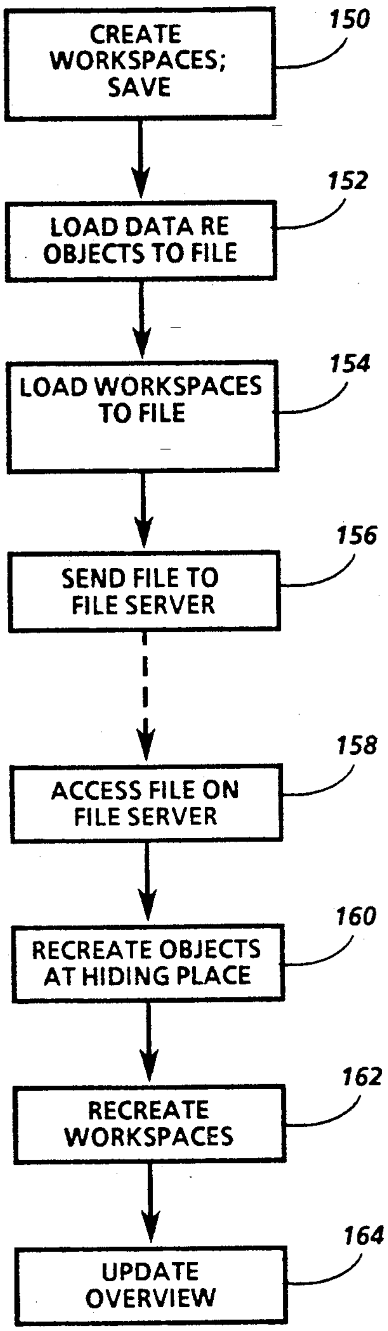

CREATE WORKSPACES; SAVE
150
LOAD DATA RE OBJECTS TO FILE
152
LOAD WORKSPACES TO FILE
154
SEND FILE TO FILE SERVER
156
ACCESS FILE ON FILE SERVER
158
RECREATE OBJECTS AT HIDING PLACE
160
RECREATE WORKSPACES
162
UPDATE OVERVIEW
164

FIG. 9

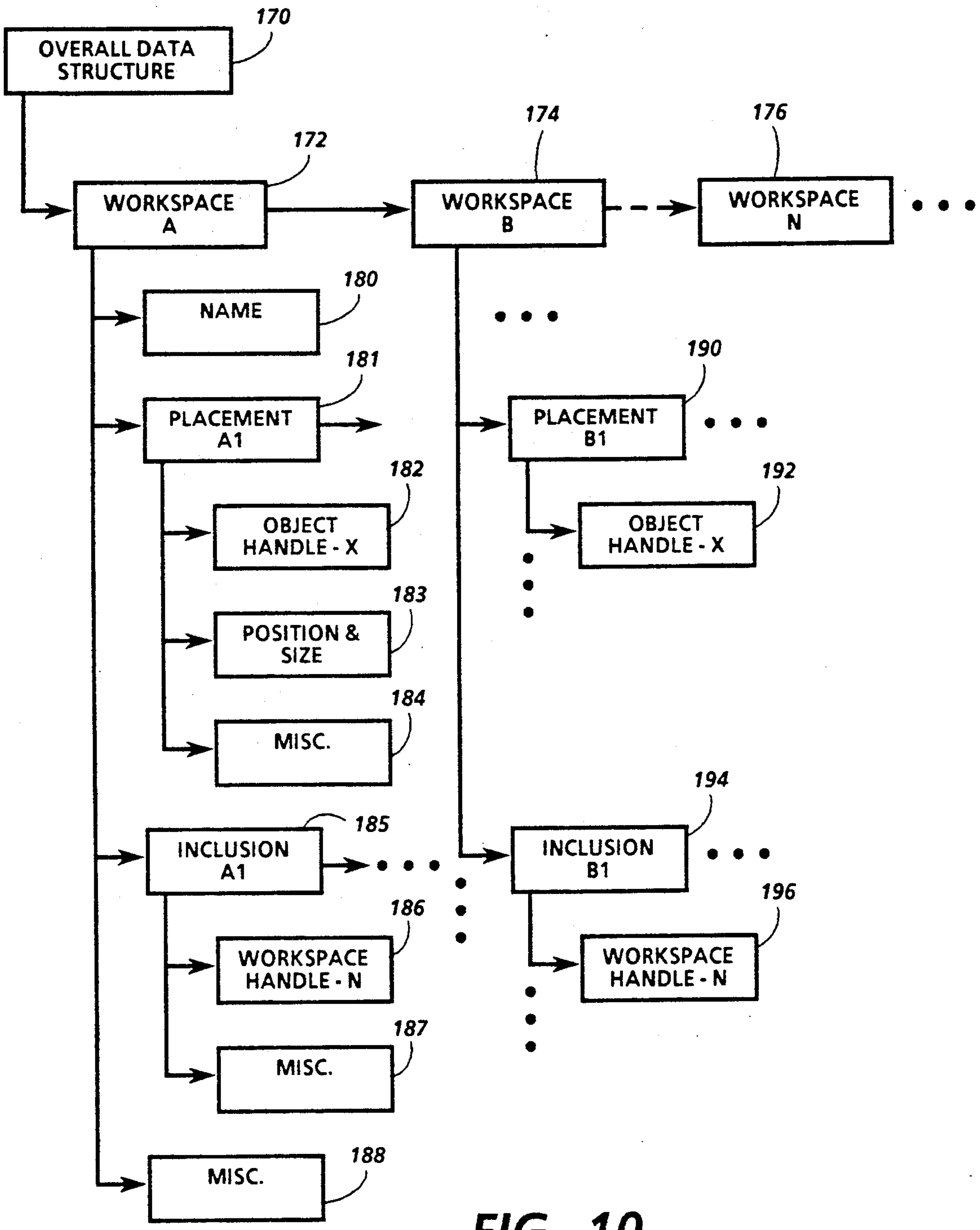
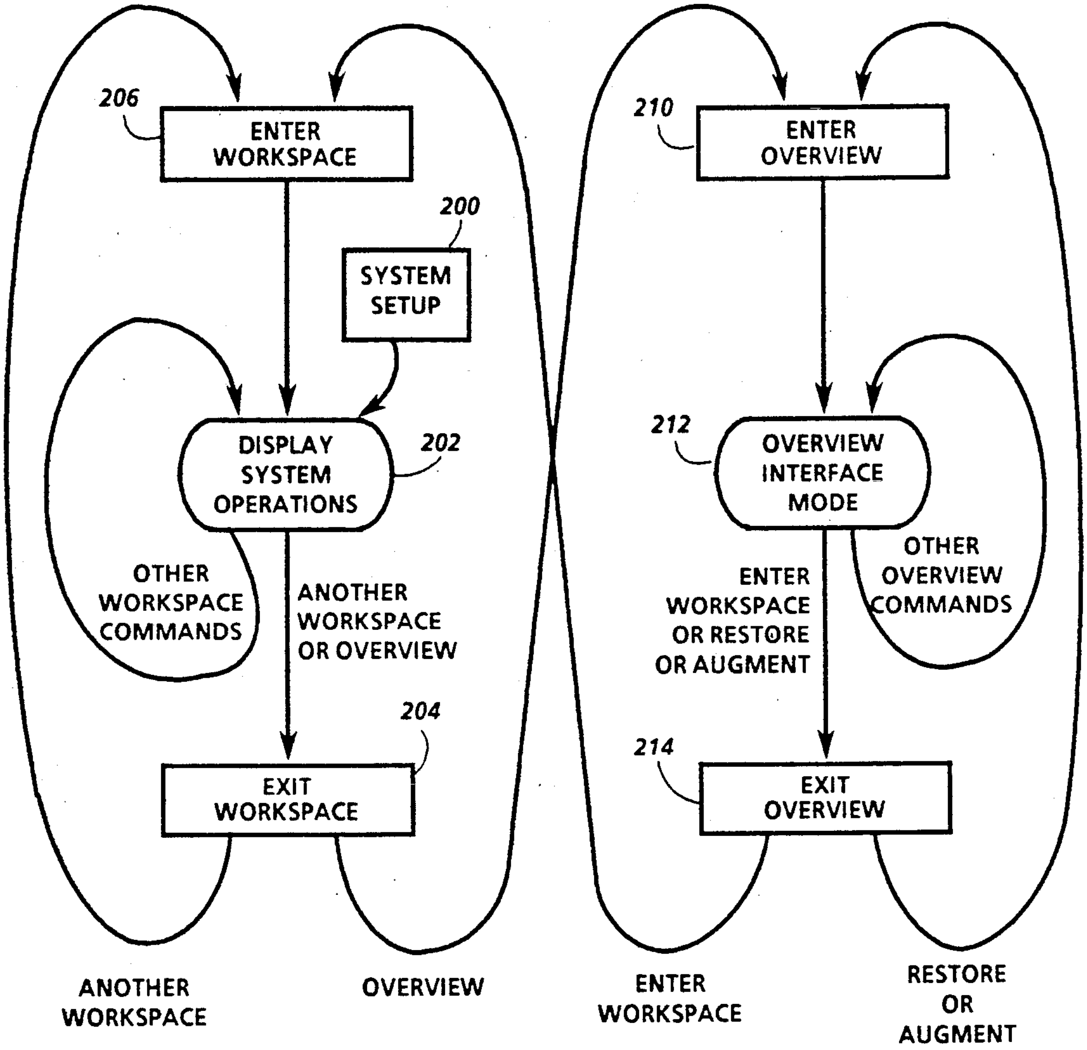
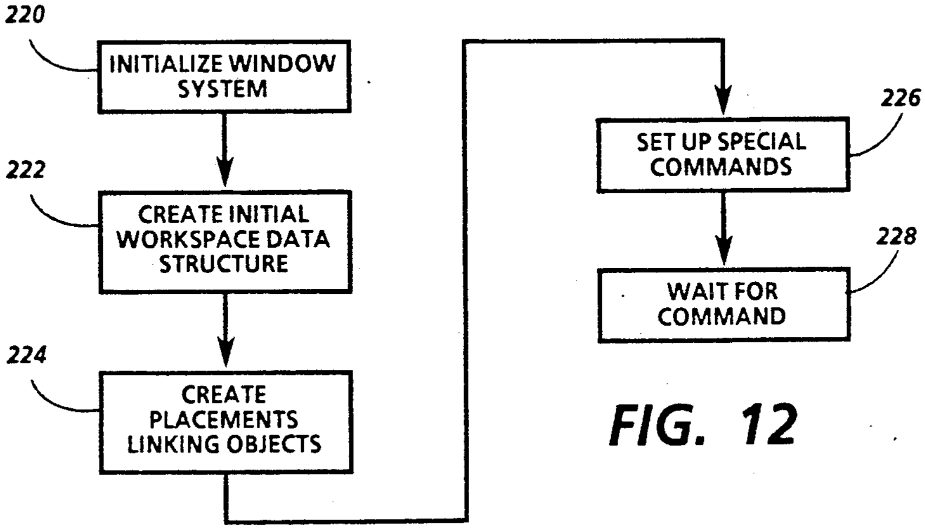

OVERALL DATA STRUCTURE
170
WORKSPACE A
172
WORKSPACE B
174
WORKSPACE N
176
NAME
180
PLACEMENT A1
181
OBJECT HANDLE - X
182
POSITION & SIZE
183
MISC.
184
INCLUSION A1
185
WORKSPACE HANDLE - N
186
MISC.
187
MISC.
188
PLACEMENT B1
190
OBJECT HANDLE - X
192
INCLUSION B1
194
WORKSPACE HANDLE - N
196

FIG. 10



206
ENTER WORKSPACE
200
SYSTEM SETUP
DISPLAY SYSTEM OPERATIONS
202
OTHER WORKSPACE COMMANDS
ANOTHER WORKSPACE OR OVERVIEW
204
EXIT WORKSPACE
ANOTHER WORKSPACE
OVERVIEW
210
ENTER OVERVIEW
212
OVERVIEW INTERFACE MODE
ENTER WORKSPACE OR RESTORE OR AUGMENT
OTHER OVERVIEW COMMANDS
214
EXIT OVERVIEW
ENTER WORKSPACE
RESTORE OR AUGMENT

FIG. 11



220
INITIALIZE WINDOW SYSTEM
222
CREATE INITIAL WORKSPACE DATA STRUCTURE
224
CREATE PLACEMENTS LINKING OBJECTS
226
SET UP SPECIAL COMMANDS
228
WAIT FOR COMMAND

FIG. 12

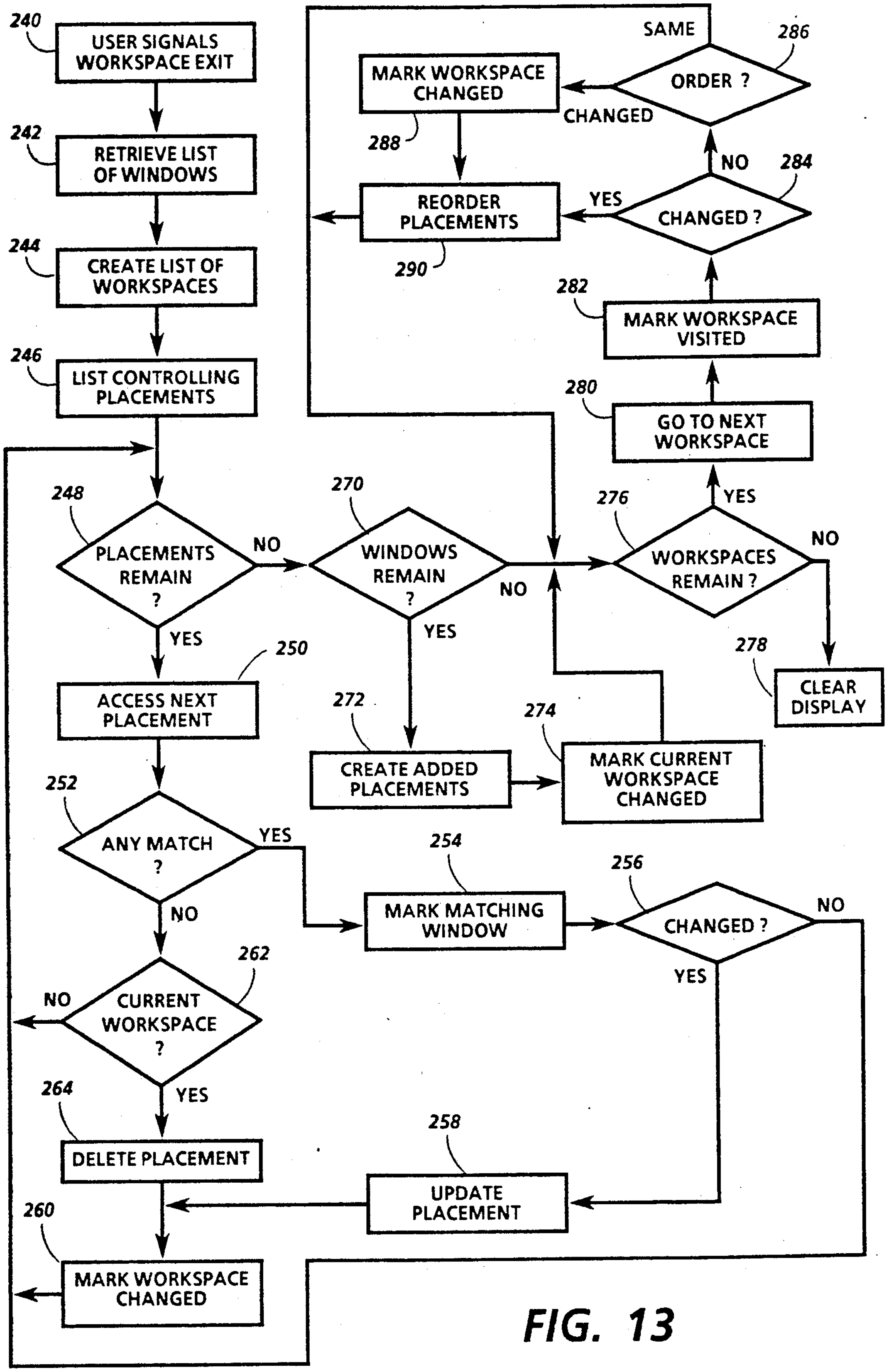
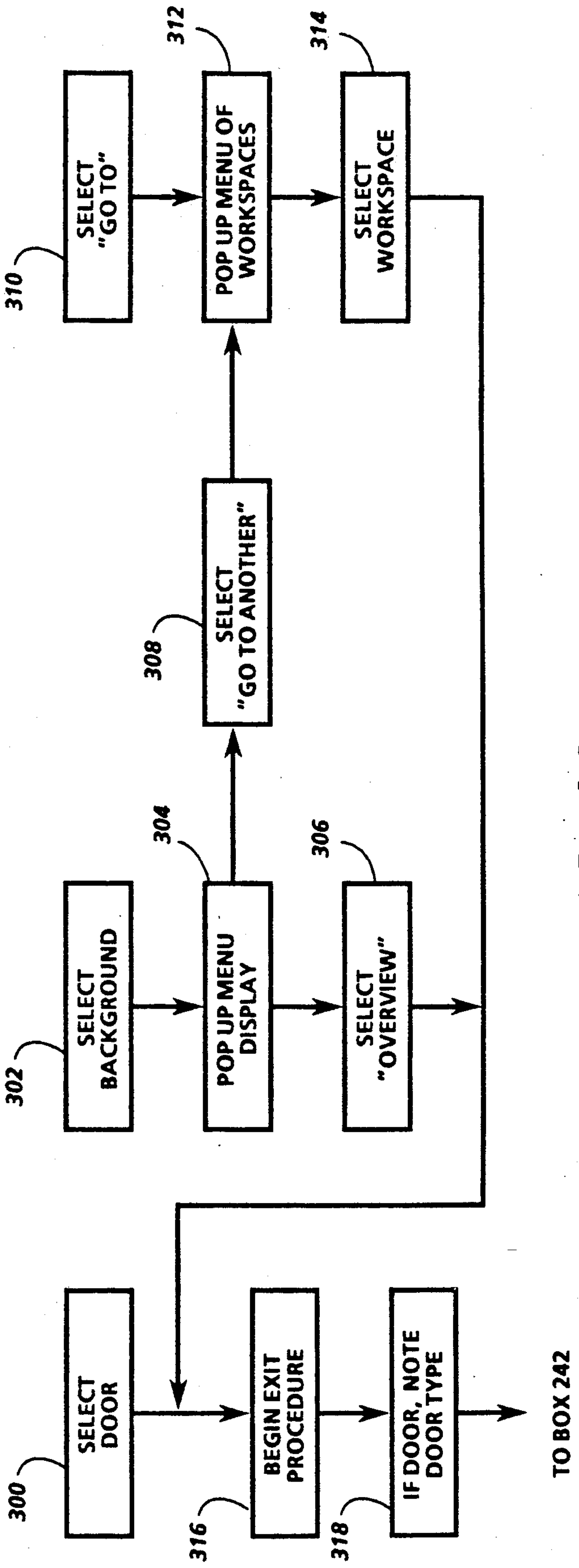
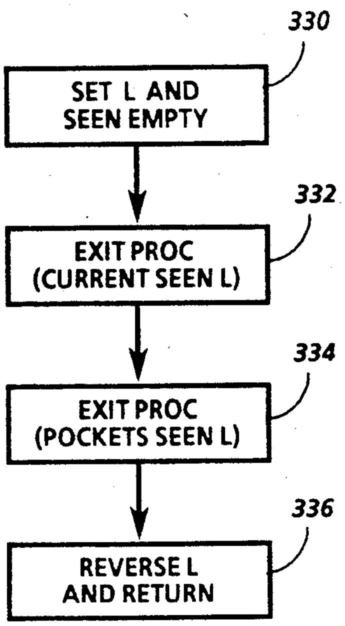

240
USER SIGNALS WORKSPACE EXIT
242
RETRIEVE LIST OF WINDOWS
244
CREATE LIST OF WORKSPACES
246
LIST CONTROLLING PLACEMENTS
248
PLACEMENTS REMAIN ?
NO
YES
250
ACCESS NEXT PLACEMENT
252
ANY MATCH ?
YES
NO
262
CURRENT WORKSPACE ?
NO
YES
264
DELETE PLACEMENT
260
MARK WORKSPACE CHANGED
270
WINDOWS REMAIN ?
NO
YES
272
CREATE ADDED PLACEMENTS
274
MARK CURRENT WORKSPACE CHANGED
254
MARK MATCHING WINDOW
256
CHANGED ?
NO
YES
258
UPDATE PLACEMENT
276
WORKSPACES REMAIN ?
YES
NO
278
CLEAR DISPLAY
280
GO TO NEXT WORKSPACE
282
MARK WORKSPACE VISITED
284
CHANGED ?
NO
YES
290
REORDER PLACEMENTS
286
ORDER ?
SAME
CHANGED
288
MARK WORKSPACE CHANGED

FIG. 13



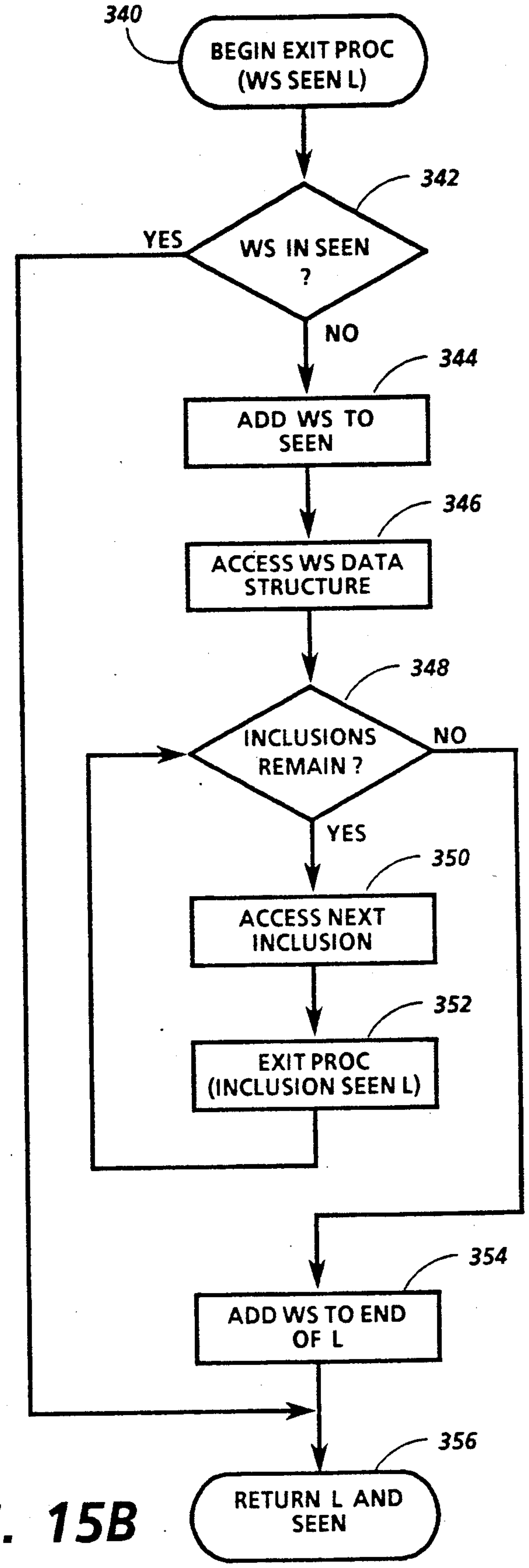
300
SELECT DOOR
302
SELECT BACKGROUND
304
POP UP MENU DISPLAY
306
SELECT "OVERVIEW"
308
SELECT "GO TO ANOTHER"
310
SELECT "GO TO"
312
POP UP MENU OF WORKSPACES
314
SELECT WORKSPACE
316
BEGIN EXIT PROCEDURE
318
IF DOOR, NOTE DOOR TYPE
TO BOX 242

FIG. 14



330
SET L AND SEEN EMPTY
332
EXIT PROC (CURRENT SEEN L)
334
EXIT PROC (POCKETS SEEN L)
336
REVERSE L AND RETURN

FIG. 15A



340
BEGIN EXIT PROC (WS SEEN L)
342
WS IN SEEN ?
YES
NO
344
ADD WS TO SEEN
346
ACCESS WS DATA STRUCTURE
348
INCLUSIONS REMAIN ?
NO
YES
350
ACCESS NEXT INCLUSION
352
EXIT PROC (INCLUSION SEEN L)
354
ADD WS TO END OF L
356
RETURN L AND SEEN

FIG. 15B

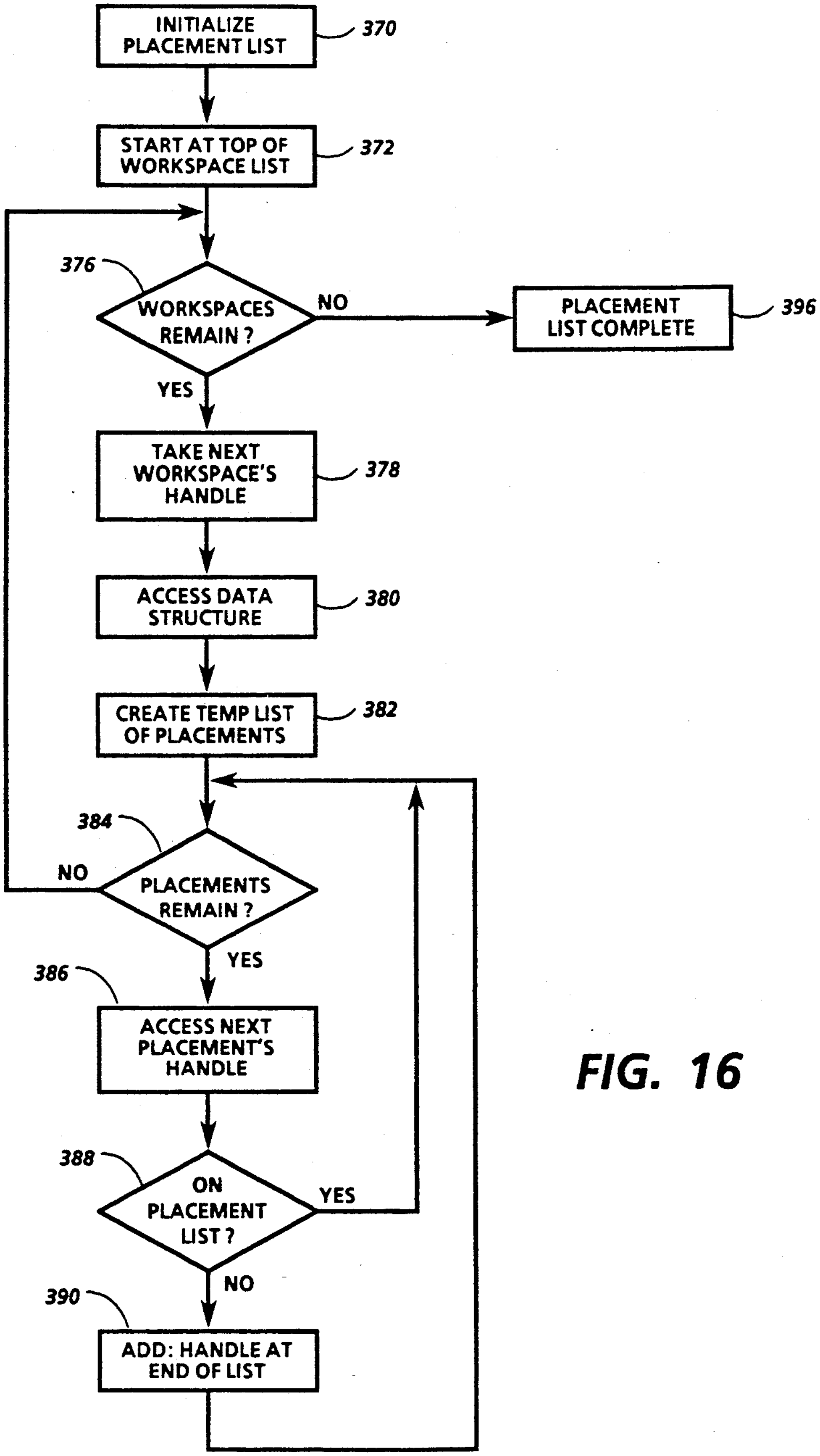
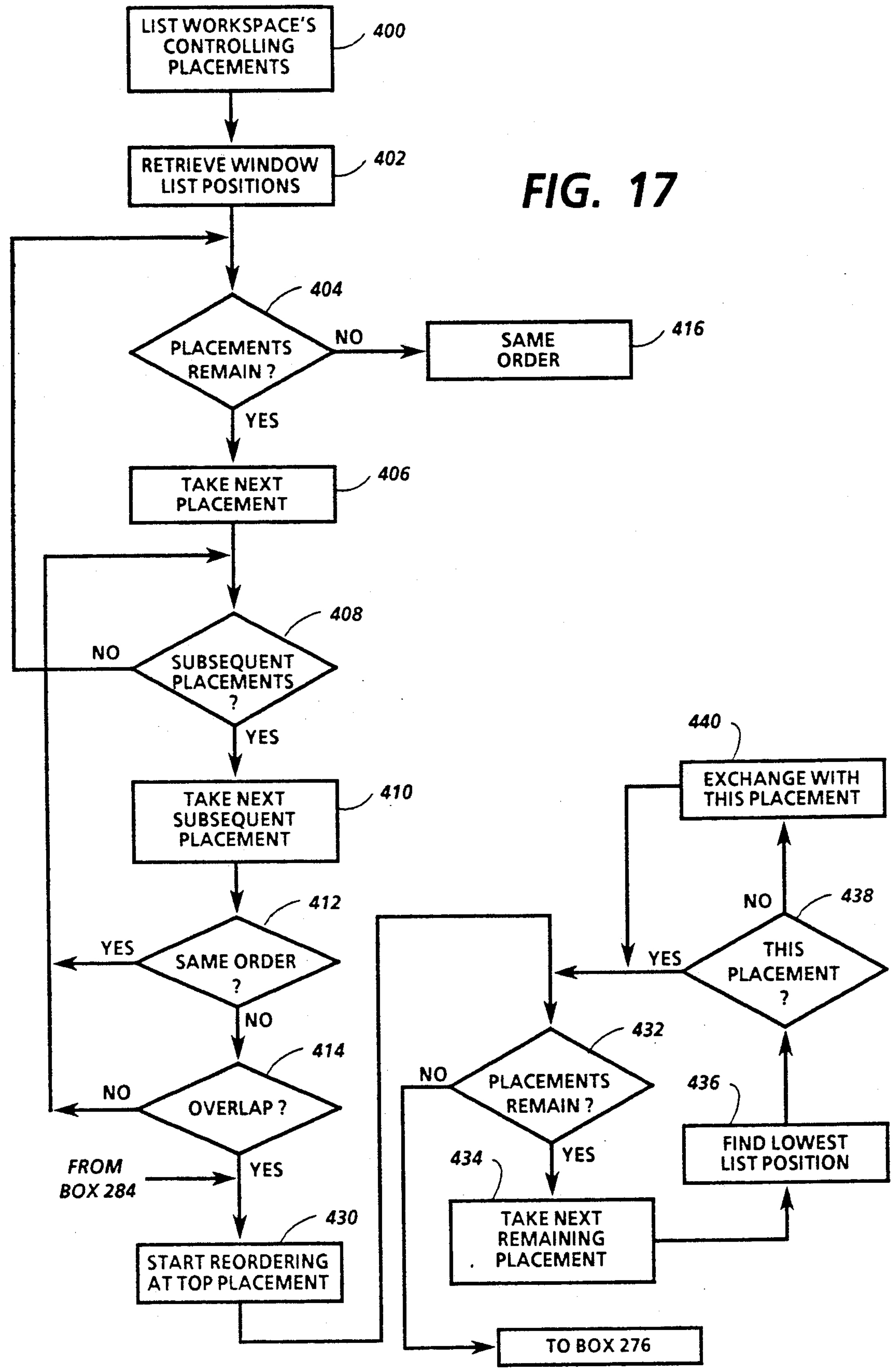

INITIALIZE PLACEMENT LIST
370
START AT TOP OF WORKSPACE LIST
372
376
WORKSPACES REMAIN ?
NO
PLACEMENT LIST COMPLETE
396
YES
TAKE NEXT WORKSPACE'S HANDLE
378
ACCESS DATA STRUCTURE
380
CREATE TEMP LIST OF PLACEMENTS
382
384
NO
PLACEMENTS REMAIN ?
YES
386
ACCESS NEXT PLACEMENT'S HANDLE
388
ON PLACEMENT LIST ?
YES
NO
390
ADD: HANDLE AT END OF LIST

FIG. 16

FIG. 17


LIST WORKSPACE'S CONTROLLING PLACEMENTS
400
RETRIEVE WINDOW LIST POSITIONS
402
404
PLACEMENTS REMAIN ?
NO
SAME ORDER
416
YES
TAKE NEXT PLACEMENT
406
408
NO
SUBSEQUENT PLACEMENTS ?
YES
TAKE NEXT SUBSEQUENT PLACEMENT
410
412
YES
SAME ORDER ?
NO
414
NO
OVERLAP ?
YES
FROM BOX 284
430
START REORDERING AT TOP PLACEMENT
440
EXCHANGE WITH THIS PLACEMENT
NO
438
YES
THIS PLACEMENT ?
432
NO
PLACEMENTS REMAIN ?
436
434
YES
TAKE NEXT REMAINING PLACEMENT
FIND LOWEST LIST POSITION
TO BOX 276

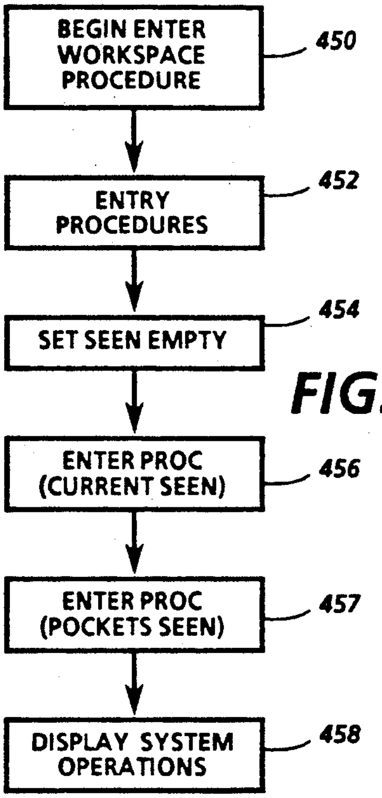

BEGIN ENTER WORKSPACE PROCEDURE
450
ENTRY PROCEDURES
452
SET SEEN EMPTY
454
ENTER PROC (CURRENT SEEN)
456
ENTER PROC (POCKETS SEEN)
457
DISPLAY SYSTEM OPERATIONS
458

FIG. 18A

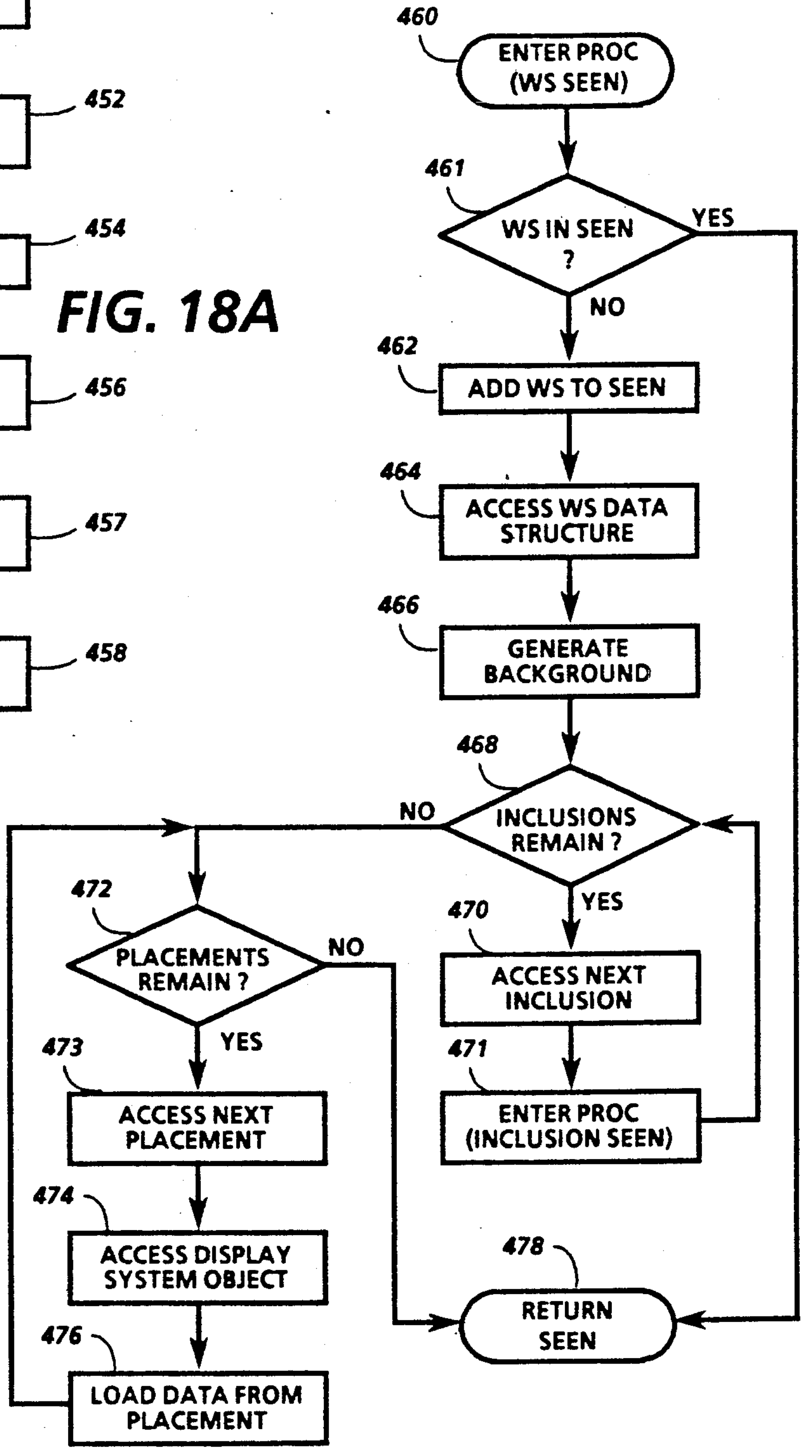

460
ENTER PROC (WS SEEN)
461
WS IN SEEN ?
YES
NO
462
ADD WS TO SEEN
464
ACCESS WS DATA STRUCTURE
466
GENERATE BACKGROUND
468
INCLUSIONS REMAIN ?
NO
YES
470
ACCESS NEXT INCLUSION
471
ENTER PROC (INCLUSION SEEN)
472
PLACEMENTS REMAIN ?
NO
YES
473
ACCESS NEXT PLACEMENT
474
ACCESS DISPLAY SYSTEM OBJECT
476
LOAD DATA FROM PLACEMENT
478
RETURN SEEN

FIG. 18B

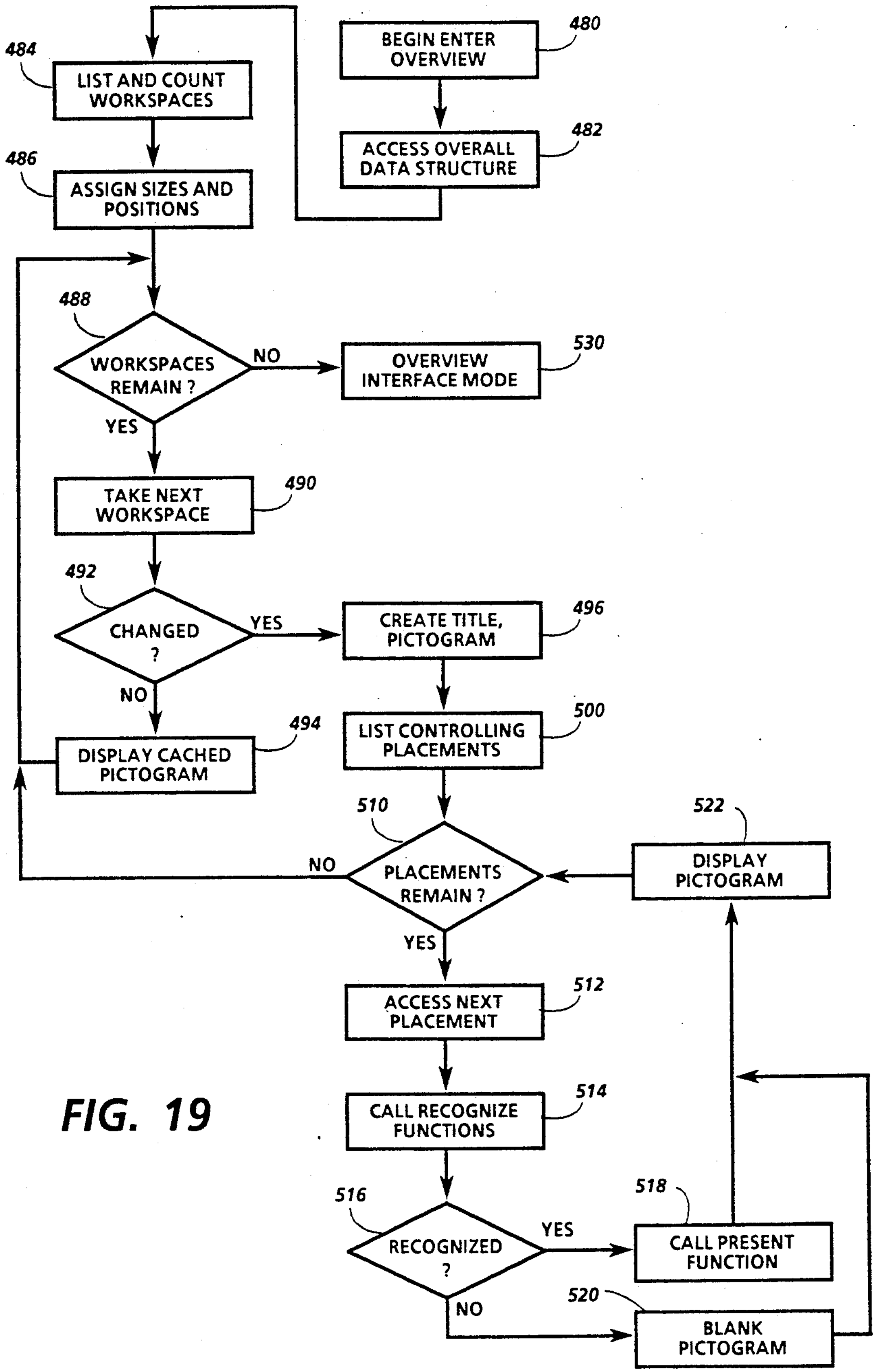
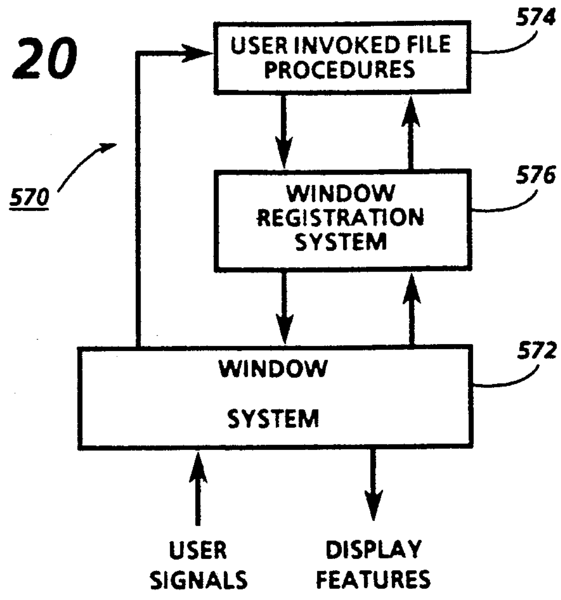

BEGIN ENTER OVERVIEW
480
ACCESS OVERALL DATA STRUCTURE
482
LIST AND COUNT WORKSPACES
484
ASSIGN SIZES AND POSITIONS
486
WORKSPACES REMAIN ?
488
NO
YES
OVERVIEW INTERFACE MODE
530
TAKE NEXT WORKSPACE
490
CHANGED ?
492
YES
NO
CREATE TITLE, PICTOGRAM
496
DISPLAY CACHED PICTOGRAM
494
LIST CONTROLLING PLACEMENTS
500
PLACEMENTS REMAIN ?
510
NO
YES
DISPLAY PICTOGRAM
522
ACCESS NEXT PLACEMENT
512
CALL RECOGNIZE FUNCTIONS
514
RECOGNIZED ?
516
YES
NO
CALL PRESENT FUNCTION
518
BLANK PICTOGRAM
520

FIG. 19

FIG. 20


574
USER INVOKED FILE PROCEDURES
570
576
WINDOW REGISTRATION SYSTEM
572
WINDOW SYSTEM
USER SIGNALS
DISPLAY FEATURES

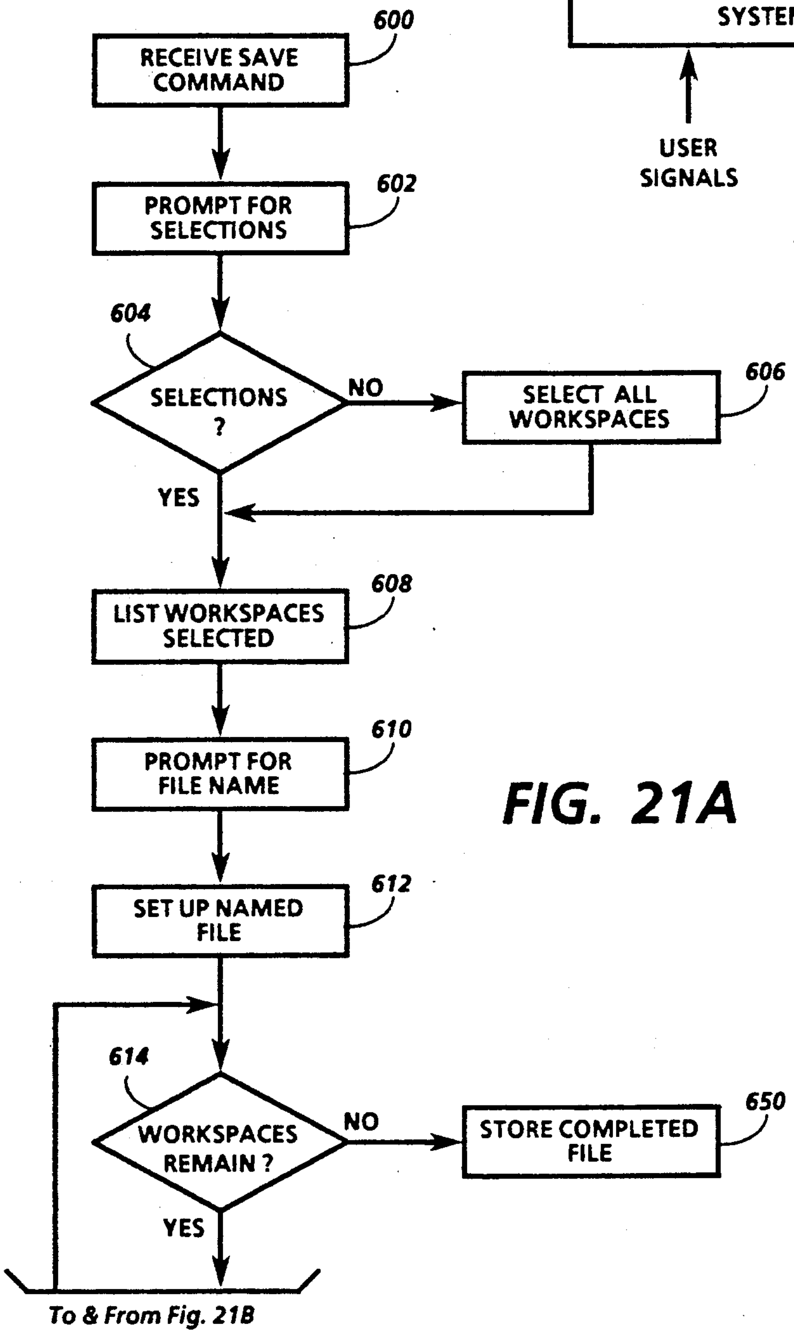

600
RECEIVE SAVE COMMAND
602
PROMPT FOR SELECTIONS
604
SELECTIONS ?
NO
606
SELECT ALL WORKSPACES
YES
608
LIST WORKSPACES SELECTED
610
PROMPT FOR FILE NAME
612
SET UP NAMED FILE
614
WORKSPACES REMAIN ?
NO
650
STORE COMPLETED FILE
YES
To & From Fig. 21B

FIG. 21A

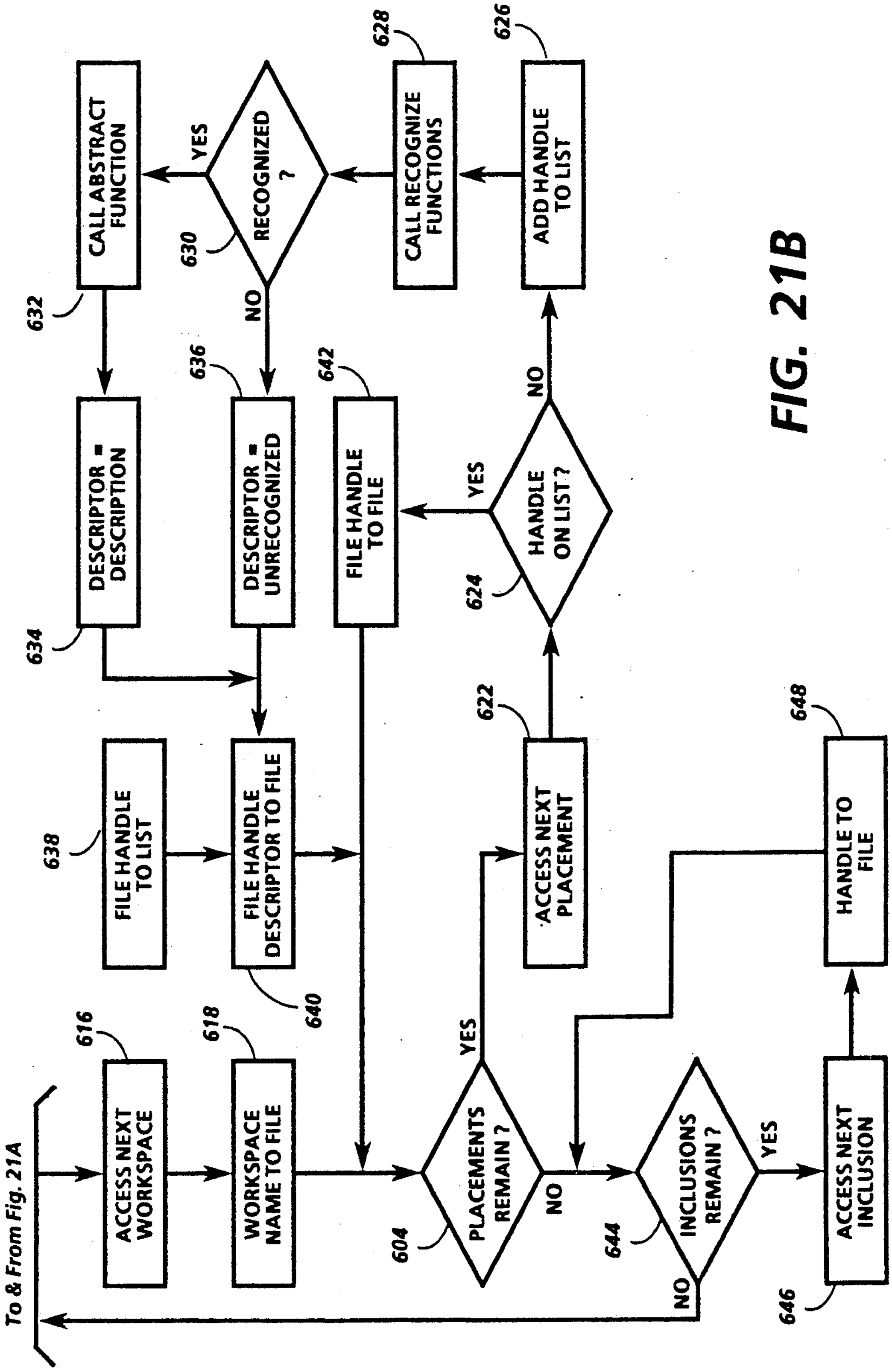

To & From Fig. 21A
ACCESS NEXT WORKSPACE
616
WORKSPACE NAME TO FILE
618
PLACEMENTS REMAIN ?
604
YES
NO
ACCESS NEXT PLACEMENT
622
HANDLE ON LIST ?
624
YES
NO
ADD HANDLE TO LIST
626
CALL RECOGNIZE FUNCTIONS
628
RECOGNIZED ?
630
YES
NO
CALL ABSTRACT FUNCTION
632
DESCRIPTOR = DESCRIPTION
634
DESCRIPTOR = UNRECOGNIZED
636
FILE HANDLE TO LIST
638
FILE HANDLE DESCRIPTOR TO FILE
640
FILE HANDLE TO FILE
642
INCLUSIONS REMAIN ?
644
YES
NO
ACCESS NEXT INCLUSION
646
HANDLE TO FILE
648

FIG. 21B

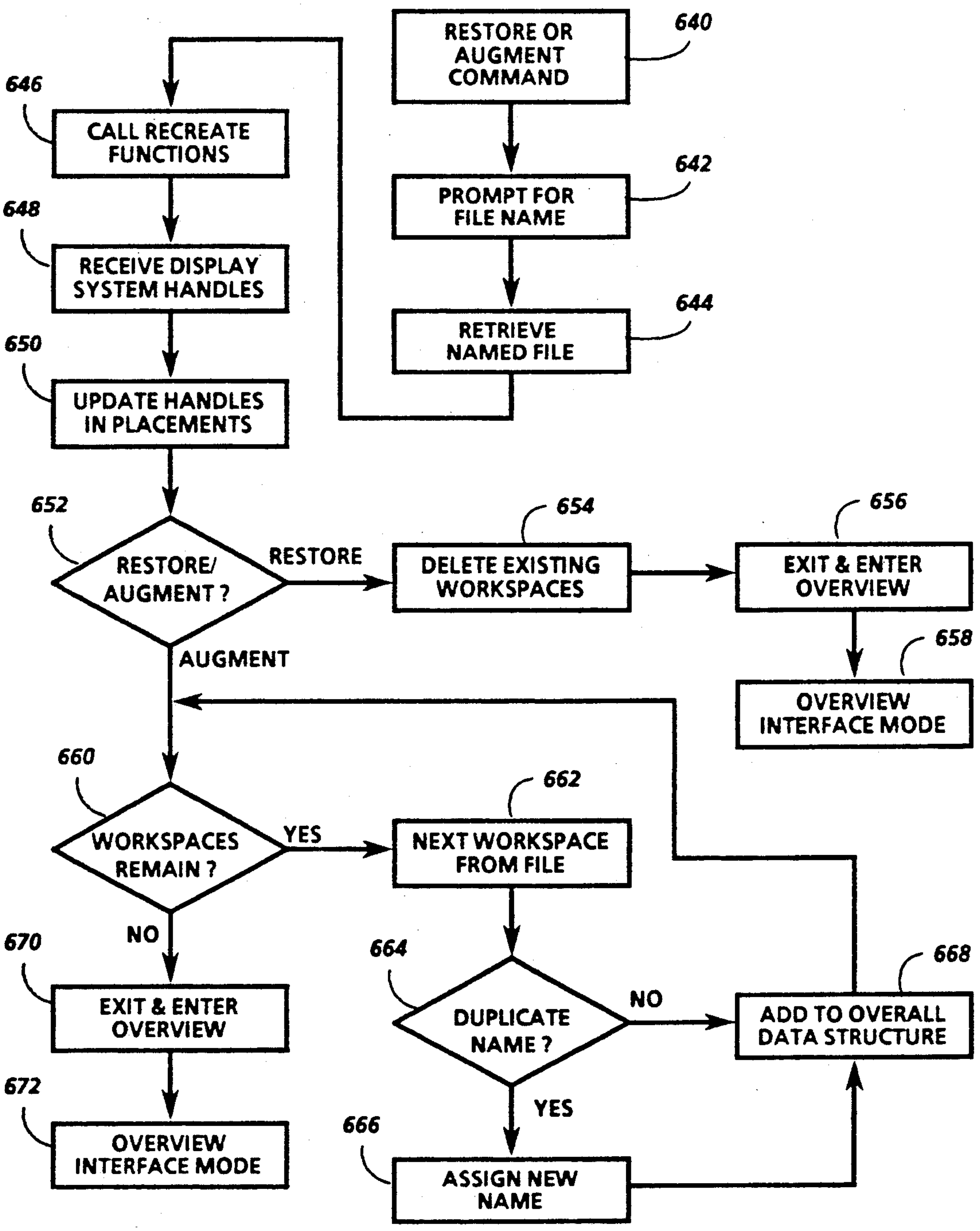

RESTORE OR AUGMENT COMMAND
640
PROMPT FOR FILE NAME
642
RETRIEVE NAMED FILE
644
646
CALL RECREATE FUNCTIONS
648
RECEIVE DISPLAY SYSTEM HANDLES
650
UPDATE HANDLES IN PLACEMENTS
652
RESTORE/ AUGMENT ?
RESTORE
654
DELETE EXISTING WORKSPACES
656
EXIT & ENTER OVERVIEW
658
OVERVIEW INTERFACE MODE
AUGMENT
660
WORKSPACES REMAIN ?
YES
662
NEXT WORKSPACE FROM FILE
NO
670
EXIT & ENTER OVERVIEW
672
OVERVIEW INTERFACE MODE
664
DUPLICATE NAME ?
NO
668
ADD TO OVERALL DATA STRUCTURE
YES
666
ASSIGN NEW NAME

FIG. 22

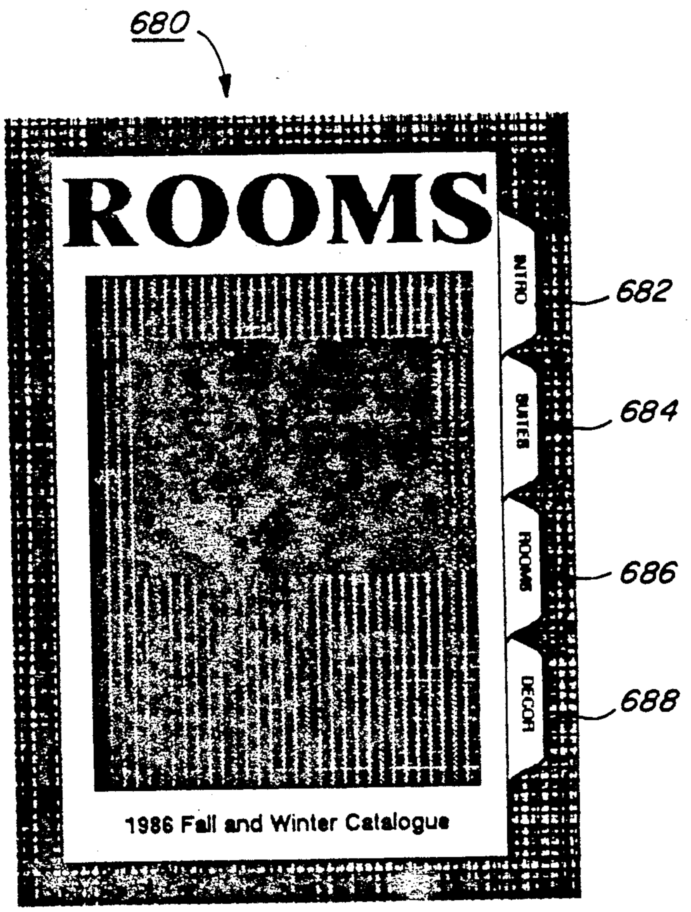

680
ROOMS
INTRO
682
SUITES
684
ROOMS
686
DECOR
688
1986 Fall and Winter Catalogue

FIG. 23

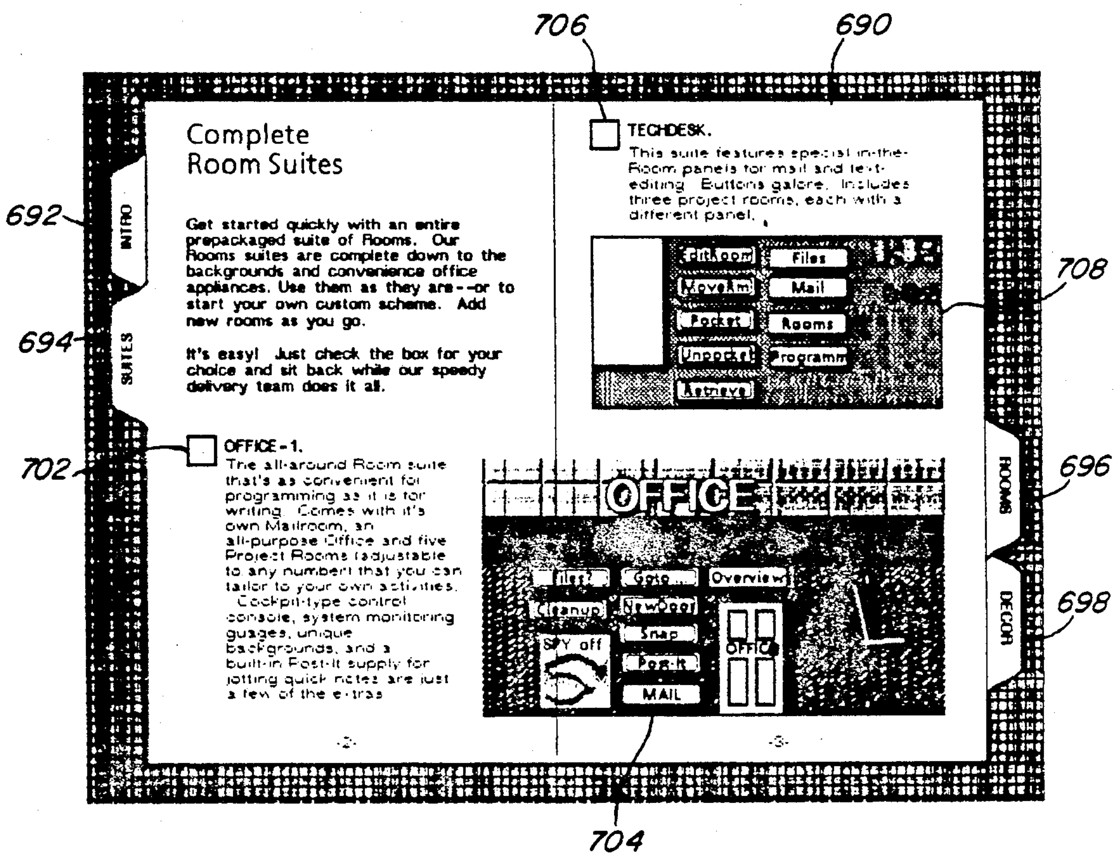

706
690
692
694
702
708
696
698
704
Complete Room Suites
Get started quickly with an entire prepackaged suite of Rooms. Our Rooms suites are complete down to the backgrounds and convenience office appliances. Use them as they are--or to start your own custom scheme. Add new rooms as you go.
It's easy! Just check the box for your choice and sit back while our speedy delivery team does it all.
OFFICE-1.
INTRO
SUITES
ROOMS
DECOR
TECHDESK.
This suite features special in-the-Room panels for mail and text-editing. Buttons galore. Includes three project rooms, each with a different panel.
Files
Mail
Rooms
Retrieve
OFFICE
Goto
Overview
Snap
MAIL
-2-
-3-

FIG. 24

USER INTERFACE WITH MULTIPLE WORKSPACES FOR SHARING DISPLAY SYSTEM OBJECTS

BACKGROUND OF THE INVENTION

The present invention relates to the user interface of a data processing system. More specifically, the invention relates to the organization of display objects such as windows into groups which are displayed together on a display-based user interface, each group being appropriate to a particular user task.

Current user interfaces typically include various types of input/output (I/O) devices-display outputs such as a cathode ray tube (CRT) and manually operated inputs such as a keyboard and a mouse. For example, a user provides alphanumeric and other inputs using the keyboard and provides inputs indicating position on the display using the mouse. The data processing system provides a display that helps the user to provide a sequence of manual inputs which will lead to the results the user desires.

One conventional technique for helping the user of a display-based user interface is to provide visually distinct display objects on the screen, each object fulfilling a corresponding function. For example, a pointer such as an arrow can be displayed on the screen, moving in response to a mouse or other pointer control device. The pointer appears to move over a number of other display objects which the user may select. The user typically selects a selectable display object or a distinct internal part of such a display object by a pointer signal, as by pressing an appropriate button on the mouse, when the pointer is on that display object or that distinct internal part. A user selection initiates operations of the data processing system which bear some logical relation to that display object.

The selectable display objects take many forms. The term "window" is applied to selectable display objects of various types, and one typical characteristic of windows is that the effect of a pointer signal within a window depends on the pointer location. The term "menu" is usually applied to another type of display object which also has this characteristic of distinct internal locations, because a menu typically has several areas within it, each of which represents an option which the user may select with a pointer signal in that area. The term "icon", on the other hand, is usually applied to a display object which does not have this characteristic of distinct internal locations, but which is a relatively small and visually suggestive of its function. A pointer signal within an icon typically produces the same effect regardless of the pointer's location within the icon.

Conventional display-based user interfaces thus may include at least three categories of display objects: a position indicating display object, such as a pointer; selectable display objects without internal location distinctions, such as icons; and selectable display objects with internal location distinctions, such as windows and menus. In addition, the user interface includes a set of procedures according to which the data processing system responds to selections and other inputs from the user.

A central constraint on user interface design is the relatively small size of the display screen, because it limits the number of perceptible objects which can be displayed to the user at any given time. On the other hand, the user tends to switch back and forth between

tasks, each relating to a different group of display objects. Bannon, L., Cypher A., Greenspan, S. and Monty, M.L., in *Proceedings of the ACM Human Factors in Software Conference, CHI'83*, (1983), pp. 54–57 and in a talk delivered by Melissa Monty at CHI'83, Boston, December 1983, describe a number of reasons for task switching. As a result of task switching, the relatively small display typically becomes cluttered with a large number of objects, many of which are not relevant to the current task.

One set of techniques permits the user to reduce cluttering by distorting display objects within the workspace which appears on the screen. Smith, D., "Pygmalion", PhD Thesis, Dept. of Computer Science, Stanford University, 1975, describes the shrinking of windows to icons or small pictures reminding the user of the contents of the window. Goldberg, A., *Smalltalk-80—The Interactive Programming Environment*, Addison-Wesley, Reading, Mass., 1984, describes the user interface of the Smalltalk-80 system, in which a rectangular area on the display in which information may be accessed is called a "view" rather than a window, and in which views may overlap, allowing windows to cover each other, leaving only a portion to remind the user of what lies behind. Smalltalk permits two independent views of a single application, so that modifications of the data engaged by that application in one view are visible in the other view, even though the two views are produced by different objects in the system. Furnas, G., "Generalized Fisheye Views", in Mantei, M. and Orbeton, P. (eds.), *Human Factors in Computing Systems—III, Proceedings of the CHI '86 Conference*, Boston, April 1986, pp. 16–23, describes a fish-eye distortion technique in which all the objects are forced to fit by selectively showing objects based on their intrinsic importance and the user's current focus of attention. Spence, R. and Apperly, M., "Data Base Navigation: An Office Environment for the Professional", *Behavior and Information Technology*, Vol. 1, No. 1 (1982), pp. 43–54 describes a similar technique. DiSessa, A., "A Principled Design for an Integrated Computational Environment", *Human-Computer Interaction*, Vol. 1, No. 1 (1985), pp. 1–47, describes a spatial box metaphor in which boxes are nested in a hierarchy, and individual boxes can either appear expanded or shrunk to a symbol, depending on the user's position in the hierarchy.

Several other techniques permit the user to reduce cluttering by allocating screen usage between a number of tasks based on a desktop metaphor. Smith, D.C., Irby, C., Kimball, R., Verplank, B., and Harslem, E., "Designing the Star User Interface", *BYTE*, Vol. 7, No. 4 (April 1982), pp. 242–282, describe the Xerox Star user interface which employs a desktop metaphor, with icons representing familiar items which would appear on one's desk or in one's office, such as a document, a file folder, or a file drawer. In this type of user interface, the allocation of screen space can be switched from one display system object to another by, for example, shrinking the windows of one task to icons and expanding the icons of another task to windows. G. Williams, "The Lisa Computer System", *BYTE*, February 1983, pp. 33–50, describes the Lisa user interface which, like the Xerox Star, employs a desktop metaphor; at pages 36–38, Williams describes icons and windows which appear on the desktop, and also describes a window capable of containing icons. The further development of these features in the Macintosh user interface is described in the MacWrite Manual and the MacPaint Manual published by Apple Computer, Inc.

Other techniques are based on a large virtual workspace metaphor in which the screen is thought of as a movable viewport onto the workspace. Sutherland, I.E., "Sketchpad: A Man-machine Graphical Communication System", *AFIPS Spring Joint Computer Conference*, Vol. 23, (1963), pp. 329-346, describes Sketchpad, an early graphical program using this technique. Bolt, R.A., *The Human Interface*, Lifetime Learning Publications, Belmont, Calif. (1984), describes Dataland, in which color pictorial and textual data are arranged in three screens, one for an overview of the whole space, one for a detailed view of some portion of the space, and one touch-screen for control. The user can translate the detailed view to a different area or zoom to obtain more detail. Donahue, J. and Widom, J., "Whiteboards: A Graphical Database Tool", *ACM Transactions on Office Information Systems*, January 1986, Vol. 4, No. 1, pp. 24–41, describe operations for examining the contents of a Whiteboard display within which objects have spatial locations. Fisher, S. S., McGreevy, M., Humphries, J. and Robinett, W., "Virtual Environment Display System", presented at ACM Workshop on Interactive 3D Graphics, Chapel Hill, N.C., October 1986, which is not prior art in relation to the present invention, describe head-mounted displays used by NASA to monitor user head and body movements and provide a complete simulated three-dimensional visual space.

Another set of techniques provide multiple virtual workspaces, allowing more convenient access to non-displayed display objects by switching quickly from one virtual workspace to another. At pages 42, 49 and 67–73, Goldberg, cited above, describes a Smalltalk display object called a "project", which is a collection of views which takes up the entire display. The projects are organized hierarchically, so that one path to each project is through a window, referred to as a "door", which appears in the display of the project in which it is created, called its parent. The user can return to the current project's parent by selecting a menu command "exit project". At pages 322–339, Goldberg describes a project browser which can also be used to access a project. The project browser has two subviews, one containing a list menu with the titles of all existing projects and the other containing editable text which describes a project being created or accessed.

Bolt, cited above, and Herot, C. F., "Spatial Management of Data", *ACM Trans. on Database Systems*, Vol. 5, No. 4 (December 1980), pp. 493–514, describe the CCA system, a further development of Dataland, in which the user is swept into a subworkspace upon zooming close enough to a port, the subworkspaces being arranged hierarchically.

Chan, P. P., *Learning Considerations in User Interface Design: The Room Model*, (Report CS-84-16) University of Waterloo Computer Science Department, Waterloo, Ontario, Canada, 1984, in Chapter 3, proposes another type of multiple virtual workspaces, the Room user interface. In this interface, a group of icons is displayed in a container called a room, with some of the icons being door icons which, when selected, result in the display of a different room. At page 26, Chan compares this with the Xerox Star user interface, noting that the Room user interface provides "multiple desktops" in the form of multiple rooms, made possibly by the door icons. In Chapter 5, Chan describes the hierarchical data structure within which each room contains the data structure of each of its icons. Chan notes in Chapter 6 that the desktop model of Xerox Star provides a single workspace, requiring the user to waste time rearranging the displayed objects, while the room model reduces this form of waste. Chan also suggests a number of additional features, including a higher level display system object for manipulating rooms and, when the attributes of an icon are being examined, growing the icon as much as necessary and leaving other icons partially visible behind the opened icon.

Feiner, S., Nagy, S., and Van Dam, A., "An Experimental System for Creating and Presenting Interactive Graphical Documents", *ACM Trans. on Graphics*, Vol. 1, No. 1 (January 1982), pp. 59–77, describe documents which are directed graphs whose nodes are referred to as pages. The pages are organized into subchapters and chapters. A page may contain a button which can provide access to another page.

Hypertext systems typically include small, often textual, networks of displayed data units connected with arbitrary patterns of typed links providing paths between locations within the data units. PROMIS, described by Hurst, J. and Walker, K. (eds.), *The Problem-Oriented System*, MEDCOM Press, N.Y. (1972), and ZOG, described by Robertson, G., McCracken, D. and Newell, A., "The ZOG Approach to Man-Machine Communication", Int'l Journal of Man-Machine Studies, Vol. 14, No. 4, May 1981, pp. 461–488, each display a single data unit at a time. NLS, described by Engelbart, D. E. and English, W. K., "A Research Center for Augmenting Human Intellect", *Proceedings of the AFIPS Fall Joint Computer Conference*, Vol. 33 (1968), pp. 395–410, provides access to a subtree of data units if screen space permits. Notecards, a product of Xerox Corporation, provides access to any arbitrary set of data units.

A problem shared by the large virtual workspace techniques and the multiple virtual workspace techniques is that the user needs help navigating. In the large virtual workspaces such as Dataland, the user may navigate much as in space, by translating and zooming, and may be assisted by having both global and local views. In multiple virtual workspaces such as Smalltalk projects, the project browser similarly can relate a limited number of projects for user navigation. In the hypertext systems such as the electronic book and NoteCards, browsers may be used as well as presentations of local connections between workspaces.

Some related features have been described in the patent literature. Ikegami et al., European Patent Application Publication No. 0,108,520, describe a method of controlling windows to display card images lengthwise on a display; a group of card images may be processed as a box, as explained at pages 4–5. Cason et al., U.S. Pat. No. 4,484,302, describe multiple virtual displays at columns 2 and 5. Shaw et al., U.S. Pat. No. 4,598,384, describe at column 2 a graphics display with independent windows, several of which may be simultaneously operated from one or more application programs. Pike, U.S. Pat. No. 4,555,775, describes graphics software under which each of several bitmap layers or windows is always active regardless of its visibility, beginning at column 1. Tabata et al., U.S. Pat. No. 4,574,364, describe a display technique in which a window management table is used to manage the information about plural windows. It would be advantageous to have a more useful multiple workspace user interface.

SUMMARY OF THE INVENTION

The present invention provides a multiple workspace user interface which has a number of useful features.

One aspect of the invention is to provide techniques for switching from one workspace display to another. The user can organize a collection of tools such as windows or other display objects into groups, with the tools of each group being linked to a respective workspace so that they are displayed when it is. A display system object can be linked to more than one workspace, to provide a respective tool in each of those workspaces. If the user provides signals causing a switch from one of those workspaces to another, the respective tools share features so that the user perceives them as the same tool, and the state of the display system object maintains continuity.

Another aspect of the invention is to provide linking data structures which can be used to link workspace data structures to the display system objects of a preexisting object-based display system. Each display system object in such a system provides a respective independent display object set, by providing each display object in that set for display and by receiving signals relating to each such display object and responding to those signals. A workspace system can be added to the display system by providing workspace data structures and procedures and by linking the workspace data structures to the display system objects using placements. More than one placement can link to the same display system object. Each placement may contain a handle for the linked object and display characteristics, such as position and size, according to which that display system object provides a display object in the linked workspace.

Another aspect of the invention is to provide techniques for leaving and entering workspaces so that the user, upon reentering a workspace, can recognize it based on its organization. In leaving a workspace, the display characteristics of the display objects are stored in the placements which link their display system objects to the workspace's data structure. When that workspace is reentered, the placements are accessed to retrieve the display characteristics, which are then provided to the display system object.

Another aspect of the invention is to provide aids to navigation between workspaces. A special navigational display called the overview can be entered from a workspace. The overview includes a pictogram representing each of the existing workspaces, within which are window pictograms representing each window within that workspace. The user may select a window pictogram to obtain more information about the corresponding display object. The user may select a workspace pictogram to enter that workspace, leaving the overview.

Another aspect of the invention is to provide techniques for the apparent transfer of display objects from one workspace to another. Although a display object cannot be transferred between workspaces, the user may select a display object and cause its apparent transfer to another workspace. The user may, for example, transfer the pictogram representing that display object between workspaces in the overview, in which case a new placement is created linking to the new workspace. The user can also move the pictogram into an included workspace, in which case it will appear to be transferred into each of the other workspaces which include that workspace. The user could put the display object into a special workspace which is effectively included in all the other workspaces. Or the user could pick up the display object in leaving one workspace so that it will be transferred into the next workspace to be entered, in which case a placement will be created linking the display object to the next workspace.

Another aspect of the invention provides techniques for manipulating workspaces, including file operations on groups of workspaces. By a save operation, descriptors of the display system objects to which the selected workspaces are linked are stored in a file and the linking placements are changed so that they contain file handles, so that the workspace data structures can be stored in the file in a form which permits recreation of the workspaces. By a restore or augment operation, the display system objects are recreated from their descriptors and their new display system handles are used to modify the linking placements so that the workspace data structures are again linked to the display system objects and the workspaces can be displayed. These file operations can be used to deliver applications. These and other objects, features and advantages of the present invention will be more fully understood from the following description together with the claims and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1A** is a schematic diagram of the display of a first workspace.

FIG. **1B** is a schematic diagram of the display of a second workspace displayed.

FIG. **2** is a schematic diagram of workspace data structures with associated placements.

FIG. **3** is a flowchart showing steps for leaving a workspace.

FIG. **4** is a flowchart showing steps for entering a workspace.

FIG. **5** is an example of an overview display showing representations of workspaces.

FIG. **6** is a flowchart showing steps for entering the overview.

FIG. **7** is a flowchart showing steps for exiting the overview.

FIG. **8** is a schematic diagram showing an inclusion linking two workspace data structures.

FIG. **9** is a flowchart showing steps for file operations on workspace data structures.

FIG. **10** is a schematic diagram showing an overall workspace data structure.

FIG. **11** is a state and transition diagram showing procedures and modes of a workspace system.

FIG. **12** is a flowchart showing steps for the system setup procedure of FIG. **11**.

FIG. **13** is a flowchart showing steps for the exit workspace procedure of FIG. **11**.

FIG. **14** is a flowchart showing a number of user signal sequences by which a user may signal a workspace exit in FIG. **13**.

FIG. **15A** is a flowchart showing steps for a routine for creating a list of workspaces in FIG. **13**.

FIG. **15B** is a flowchart showing steps of a recursive procedure called in FIG. **15A**.

FIG. **16** is a flowchart showing steps for creating a list of controlling placements in FIG. **13**.

FIG. **17** is a flowchart showing steps for testing the order of placements and for reordering placements in a workspace in FIG. **13**.

FIG. 18A is a flowchart showing steps for a routine for walking through a workspace data structure to enter a workspace.

FIG. 18B is a flowchart showing steps of a recursive procedure called in FIG. 18A.

FIG. 19 is a flowchart showing steps for entering the overview.

FIG. 20 is a schematic block diagram showing the window registration system.

FIGS. 21A and 21B are a flowchart showing steps for a save operation on workspaces.

FIG. 22 is a flowchart showing steps for a restore operation and an augment operation on a saved file.

FIG. 23 shows a display object for delivering applications which may be used with the augment operation of FIG. 22.

FIG. 24 shows another display object for delivering applications which is available from the display object of FIG. 23.

DETAILED DESCRIPTION

A. Conceptual Framework

The following terms provide a conceptual framework for describing the present invention.

A "display object" is defined herein as a visually distinguishable display feature or set of features which is coherent, in the sense of sticking together in a display. An alphanumeric character is a common display object, and early user interfaces typically were only capable of displaying such objects. Windows and icons, described above, are more advanced display objects. Some display objects, such as characters within an icon's label, may not be separately user selectable, while others, such as the icon itself, may be selected for the performance of a specified operation. The types of display objects available, the manner in which they are selected and the available operations are all characteristics of the particular system providing the display, and the system includes hardware and software components.

The term "container" is defined herein to mean a display object which may contain other display objects within its boundaries. A window is an example of a container because it may be occupied by a number of characters or other display objects. A window is itself a display object, however, so that the display characteristics of the window, including its dimensions, place a constraint on the display objects it contains. A container such as a window may, however, remain invisible when displayed, even though display objects it contains are visible. Also, a container may be location sensitive, meaning that a user selectable display feature within it may be selected by user signals indicating the location of that feature. In general, a container may be analyzed into display characteristics, such as position, size and other features which depend on the particular presentation, and its contents, including the display objects and other features which do not depend on the particular presentation.

The term "display system" is defined herein to mean a system for managing or controlling a display. A display system is therefore an example of the more general term "user interface", meaning a system for receiving signals from a user or for providing signals to a user, or both. The user interface will typically be one of a number of subsystems within an overall system.

An "object-based display system" is a display system that presents a number of display objects as if each was an independent object, meaning that each of those display objects appears to the user as if it were receiving signals from the user and responding to those signals independently from the other display objects, according to its own receiving and response procedures. The display objects that are managed in this manner may include containers such as windows and also non-containers such as icons. An object-based display system may also present several display objects as if they were not independent, such as two windows that differ in position and size but have the same contents or a window and its icon or shrunken form. Each group of display objects that are not independent of each other but that are independent of all other display objects is referred to herein as an "independent display object set". An object-based display system can be implemented in a multitude of ways. An object-based display system for managing windows, for example, is referred to herein as a "window system", and each independent display object set in a window system can be interactively manipulated independently of other windows not in that set.

The term "display system object" is defined herein to mean the means within an object-based display system for providing a corresponding independent display object set, meaning that the display system object provides the visible features of each of the display objects in that display object set and receives and responds to user signals relating to those display objects. A display system object may include one or more data structures and a number of procedures, and a data structure or procedure such as an editor or other application could be called by more than one display system object, each of which also includes a respective set of changeable display characteristics for presenting the corresponding display objects. Each window in a window system, for example, is provided by a display system object, which determines not only the contents of the window but also the display characteristics of the window. A single display system object may provide more than one window if those two windows are not independent of each other and may also provide an icon or shrunken form of a window it provides. A display system object is one instance of the more general term "signal source", meaning any means for generating data that a user can perceive.

The term "display workspace", or simply "workspace", is defined herein to mean the display system entity that includes a collection of display objects together with spatial display relations between them. A workspace is referred to as being displayed when the display objects in it are available for display in accordance with the spatial display relations they have within that workspace. The workspace itself need not be visible as a distinct display object when it is displayed and could occupy the entire display area. The display objects within it may be user selectable, and if a display object is selectable by user signals indicating its location within the display, the workspace is location sensitive. A display system or part of a display system that manages or controls workspaces is termed a "workspace system". A workspace system may be implemented in many ways, some of which are described below.

A workspace system may provide only one workspace that is always displayed, or it may provide more than one workspace, in which case one or more of the workspaces may not be displayed at times. Workspaces may thus be referred to as "virtual workspaces", with the display objects in each workspace being available for display when that workspace is displayed. In other words, the workspace itself is virtual, yet a part of it may be made real by being displayed.

The more general term "perceptural space", or simply "space", is used herein to refer to any range of perception that may be occupied by signals which are distinguishable by a user. A display workspace is but one example of a space, the type of space that display objects like windows and icons may ocupy. Another example of space would be the perceptual space that different tones or voices may occupy.

In general, the distinguishable signals generated by a user interface, whether windows or voices, may be referred to as "user interface objects". An "object-based user interface system" is one that can provide a number independent user interface objects, meaning that each of these objects seems to the user to be receiving signals from the user and responding to those signals independently from the other objects, according to its own receiving and response procedures. An object-based user interface system may also present several user interface objects as if they were not independent, and each group of objects that are not independent of each other but that are independent of all other objects is referred to herein as an "independent interface object set". An "interface system object" is the means within an object-based user interface system for providing each of the user interface objects in a given independent interface object set and for receiving and responding to user signals relating to those user interface objects.

The above terms have the meanings indicated above both in the following description and in the attached claims.

B. General Features

FIGS. **1-9** illustrate a number of general features of the present invention, including switching from the display of one workspace to another; placements linking display objects to workspaces; methods of leaving and entering workspaces; aids to navigating between workspaces; techniques for transferring display objects from one workspace to another; the inclusion of a workspace in another workspace; techniques for manipulating workspaces; and techniques for transferring a group of workspaces.

1. Workspace Display Switching. FIGS. **1A** and **1B** each show a respective display screen presenting a plurality of display objects. These display screens are examples of workspace displays, each displaying part or all of a workspace occupied by a number of distinguishable display objects, such as windows and icons.

Workspace display **10** in FIG. **1A** is a display of a first workspace, which includes windows **12** and **14** and icon **16**, positioned within display **10** in accordance with their spatial relations within the first workspace. Window **12** presents several alphabetic characters from a text editing application and window **14** presents a triangular solid from a graphics application. Each of these windows may be location sensitive, so that the user, by selecting a location within a window and invoking an operation, can send a signal corresponding to that location to the display system object providing that window. For example, in an editing window, the user may modify a display feature by selecting the location at which that feature is displayed and invoking an editing operation. Door icon **16**, on the other hand, is not location sensitive. Pointer **18** is currently pointing at door icon **16**, and if the user provides a select signal at this time, door icon **16** will be selected as a unit, without regard to the position of pointer **18** within the icon. The user may then invoke a door opening operation, causing workspace display **10** to disappear and workspace display **20** to appear, as shown in FIG. **1B**.

Workspace display **20** is a display of a second workspace, which includes windows **22** and **24** and icon **26**, positioned in accordance with their spatial relations within the second workspace. Window **22**, which is provided by the same display system object as window **12** in workspace display **10**, is presented in a different location on the screen and with different dimensions than window **12**, as can be seen from the cutting off of the character "d". Window **24** presents a cylindrical solid from another graphics application and a different door icon **26**, a "back door" that can be used to return to workspace display **10**.

Workspace displays **10** and **20** each include a group of display objects as described above. As noted, two of those display objects, windows **12** and **22**, are provided by the same display system object, which calls a text editing application as one of its procedures. If the user edits the contents of window **12** and then uses door icon **16** to enter workspace display **20**, the changes made will be reflected in the contents of window **22** and the state of the underlying display system object will be continuous. It is also possible for the user to remove window **12** from workspace display **10** without removing window **22** from workspace display **20**.

Windows **12** and **22** illustrate the phenomenon of object constancy, under which two successively displayed objects are perceived as the same object. Object constancy can result from many cues, including position, size, context, contents, labels, history and so forth. Here, windows **12** and **22** appear to be the same object despite having different display characteristics, including different positions, sizes and contexts. But because they each contain a fragment of shared text, the user typically perceives them as the same object. That perception is reinforced if they also share response procedures so that user invoked operations, such as scrolling or selecting and operating on contents, have the same effect in each window. Other shared features which can result in object constancy include sharing of an application, such as an editor; sharing of data; sharing of the state of the application as applied to the data; sharing of a history of continuous operation without interruption, i.e. without disengaging the application from the data.

The above described features of the present invention are based on the recognition of a problem which previous user interface techniques have not completely solved, the problem of tool faulting, which precludes fast task switching. Tool faulting is not limited to a display-based user interface, but occurs in any object-based user interface. Each user interface object in effect serves as a tool, and the user treats each tool as an external memory or processor that augments the user's own capabilities. These tools could be display objects, audible objects or entities, mechanical gesturing objects, tactile objects or objects providing any other signal perceptible by the user.

The invention is based in part on the recognition that a user's activities are organized around tasks, during each of which the user employs a collection of tools appropriate to that task. This phenomenon is called locality of reference, meaning that within any given short period of time the number of different tools employed will be small while the number of instances of use of each tool employed is relatively high. Therefore, references to tools occur in clusters. These clusters are separated, however, by distinct task switches, during which the user stops employing one collection of tools and begins to employ a different collection. When the task switch is completed, a cluster of references to the new collection of tools will occur, followed by another task switch, and so forth.

The problem can be understood more fully by considering the capacity and access time of such a tool. If the user interface is display-based, for example, the number of display objects to which the user has direct access is limited by the size of the display. The user tends to increase the number of visible display objects and also to increase the size of each display object in accordance with current needs, up to the limit imposed by the display size. This tendency conflicts, however, with the need for a different set of tools when a task switch occurs.

During a task switch, the user needs fast access to the tools associated with the new task that are not currently available, and the process of accessing each such tool is referred to as a tool fault, during which the user does whatever is necessary to find that tool and make it available for use. In a display-based user interface, for example, it may be necessary to obtain a window with a command or a menu or by expanding an icon or it may be necessary to make a window visible by making it the top window or by inactivating, resizing or moving other windows. A tool fault thus provides access to a tool which is unavailable on the display but needed; and amount of time spent by the tool fault may be greater if the tools being used previously required a large amount of display area. In other words, there may be a tradeoff between the display area currently being used and the access time for a different set of tools.

The present invention is further based on the recognition that this problem cannot be solved simply by organizing the tools into mutually exclusive groups between which the user can switch. The user may require a given tool during a number of tasks. If the tools are organized into mutually exclusive groups, a great deal of tool faulting will still be necessary to access such tools.

The present invention solves this problem by enabling the user to organize the tools into groups among which tools may effectively be shared and between which the user can rapidly switch. The tools of each group occupy a respective perceptual space and, when presented to the user, are free to occupy substantially all of the system-to-user capacity of that space. The user is able to provide a sequence of signals that causes a switch from one space to another space. When the user switches from a first space to a second space, as by going from one workspace to another using a door icon in a display-based interface, tool faulting occurs much more rapidly for the group of tools than if the user had to handle each tool fault individually. And if the first and second workspaces share a tool, a first display object in the first workspace and a second display object in the second workspace share features so that the user perceives them as the same display object or tool and can continue working with the second display object on that basis. Therefore, the invention permits fast and effective task switching.

2. Placements. Another aspect of the invention is based on the recognition that a number of software systems which provide display objects such as windows and icons already exist. Because a window system requires voluminous software, it is undesirable to rewrite the entire window system software in order to implement the above described features of the invention. This aspect of the invention is based on the discovery of techniques for implementing workspaces with an existing window system without extensively modifying the existing window system's software. Because some of those techniques permit a distinction between the window system which manages the windows and the workspace system within which the windows are displayed, the window system and the workspace system can develop separately.

FIG. 2 illustrates part of a data structure used in implementing the invention in a manner requiring only minimal changes in a window system used with it. The data structure includes workspace data structure **30** for workspace **10** displayed in FIG. **1A**, and this workspace data structure has a number of associated data structures including placements **32** and **34**. A placement is a data structure which links a respective workspace to a display object included in that workspace. A placement may also include data about the display characteristics of that display object when displayed within that workspace, from which the spatial display relations of that display object to other display objects in that workspace may be determined. For example, workspace data structure **30** includes data for providing workspace display **10**, while placement **32** provides the location and size of window **14** and placement **34** provides the location and size of window **12**.

Each placement is linked to a display system object, and if the workspace system is implemented with a preexisting window system each display system object is within the window system. When a workspace display is set up, each placement linked to its workspace data structure provides the location and size of a window or other display object to the display system object which provides that window. Placements **32** and **34** respectively link display system objects **36** and **38** to workspace data structure **30** so that windows **14** and **12** are presented in workspace display **10**. Similarly, placements **42** and **44** link display system objects **46** and **38** to workspace data structure **40** so that windows **24** and **22** are presented in workspace display **20**. Placements, not shown, could also link display system objects to the workspaces so that doors **16** and **26** are presented.

Because a display system object may be linked by different placements to different workspaces, the contents it provides may be displayed differently in those workspaces. For example, placements **34** and **44** in FIG. **2** link workspace data structures **30** and **40** with a shared display system object **38**, making it possible for window **12** in workspace display **10** to have the same contents and receiving and response procedures as window **22** in workspace display **20** while having a different position and size. At the same time, placement **32** retains display placement data about window **14** in workspace display **10** even while workspace display **20** is visible so that when the user selects door icon **26**, workspace display **10** returns with window **14** presented at the appropriate position and size. Placements thus make it possible for each of a number of windows with the same visible contents and receiving and response procedures to appear in a respective workspace at a unique position and size. This is possible even though the shared contents and procedures of all of the windows are from a single display system object which is part of an independent window system. This feature of placements is also applicable to display objects other than windows.

3. Leaving and Entering a Workspace. Another aspect of the present invention is based on the recognition that the transition from one workspace to another may be confusing to the user unless the newly displayed workspace has some distinctive identifying characteristics and familiar organization and contents. This problem is closely related to the problem of fast task resumption, because a user is not able to resume a task quickly unless the display provides cues about the user's previous place in that task. This aspect of the invention is based on the discovery of techniques which assist the user in recognizing a newly displayed workspace. One technique is to provide identifying visual features such as a distinctive background or name to appear with the newly displayed workspace. In order to give the user a sense of familiarity with the organization of the workspace, however, it is also important that the display objects within the workspace appear with the same organization as when the user last left that workspace. Also, the contents of each window, to the extent not modified through windows in other workspaces, should appear the same as when the user last left. In order to return the display objects to the same state, appropriate information must be stored when the user leaves a workspace.

FIG. **3** shows a sequence of steps for leaving a workspace according to the invention. In box **60**, the user initiates the operation of leaving a workspace by signaling that the display system should display another workspace or the overview, a user interface feature discussed below. In either case, it is necessary to preserve the state of the currently displayed workspace before leaving it, and the system will lock out the user temporarily so that it can perform the necessary steps to do so.

In box **62**, the system stores data about the currently displayed objects in the placements which link them to the currently displayed workspace. This data may be retrieved based on the changes the user has made while in the current workspace, as discussed in more detail below. Some or all of this data could alternatively be maintained during operations in the current workspace by updating a list of the placements controlling currently displayed objects whenever an operation changes the data in a placement. In either case, the data stored in the placements includes any feature of each display object which can be different when it is displayed in different workspaces. Therefore, the placement data should include at least the position and size of the display object, and may also include other features of its appearance. It is necessary to store this data so that when the user again enters this workspace, the display objects in it can be caused to appear the same as when the user left.

The system proceeds in box **64** to make the display objects in the current workspace invisible. Because display objects with the same contents may appear in other workspaces, the contents may be modified before the user reenters the current workspace. Therefore, it is not possible to ensure that the contents will remain the same. But each display object must be removed from the display so that the next workspace can be displayed, and the display system object providing the contents of each active display object such as an open window should be kept active. When those contents are next displayed, either in another workspace or upon reentering this workspace, they should be the same as when this workspace was left, and the state of the display system object providing them should be continuously active, without interruption. One technique for removing the contents of a window without changing the state of the respective display system object is to cause the display system object to provide those contents to a dummy position, called a "hiding place" herein, in which they will be ignored in creating the display. While those contents are being provided to the hiding place, it is important that the display system object not receive user signals, of course, and it is convenient to think of the display system object itself as being in the hiding place. Another technique is to use a boolean variable in the display system object to cause it to stop displaying any display object until that boolean variable is reset. Whatever technique is used, each display object would be invisible upon completion of the step in box **64** and would remain invisible until displayed again in a workspace.

The step in box **66** provides for procedures upon leaving a workspace, which may be unique to that workspace. Procedures in box **66** may preserve useful information about the workspace itself, as opposed to the steps in boxes **62** and **64** which preserve useful information about the workspace's placements and their respective display system objects. For example, an identifier of the current workspace may be stored in a location which indicates that it is the previous workspace. In addition, information may be stored about the manner in which it was left. Procedures may be performed for transferring the contents of a display object in the current workspace to a new display object provided by the same display system object in the next workspace. Also, user supplied procedures for modifying the system, for example by changing global variables, may be performed. When all of these procedures are completed, the system enters the next workspace or the overview, in box **68**.

FIG. **4** shows a sequence of steps for entering a workspace, which is generally the reverse of the sequence in FIG. **3**. In box **80**, the workspace's data structure is accessed using an identifier of that workspace. The workspace identifier may result from a user signal to enter that workspace. Upon accessing the workspace's data structure, its entry procedures are performed in box **82**. Those procedures may include providing a way to return to the previous workspace and storing this workspace's identifier in a location indicating it is the current workspace. In box **84**, the system retrieves the data about the display objects in this workspace from the placements associated with this workspace's data structure. The linked display objects are then made visible in accordance with that data in box **86**, which includes moving them from the hiding place to a location within the display. At this point, the system is ready to receive further user inputs.

The process of leaving and entering a workspace, as shown in FIGS. **3** and **4**, thus returns the display objects in a newly displayed workspace to approximately the same state as when the user last left that workspace. The invention thus solves the problem of fast task resumption, because the user is ordinarily able to recall the resumed task based on the organization and contents of its display objects.

4. Navigation Aids. Another aspect of the invention is based on the recognition that the user must have the ability to navigate efficiently between workspaces. This

problem involves several more specific problems. The user is very likely to need an efficient way to return to the previous workspace. The user should be able to find and enter any other workspace. The user should be able to find a desired display object in any other workspace.

A return to the previous workspace can be provided by creating a back door to the previous workspace in the step in box **82** in FIG. **4**. Also, access to any other workspace can be provided by a pop-up menu with a list of all existing workspace names. But it would be beneficial to have a more powerful navigational tool.

This aspect of the invention is further based on the recognition that many navigational problems can be solved with a user interface feature which displays the existing workspaces together with information which assists the user in finding display objects within workspaces. In accordance with the invention, this feature is implemented by a special display referred to as the overview.

FIG. **5** shows overview **100**, with eleven currently existing workspaces, each represented by a pictogram. Workspace pictogram **102**, for example, represents a workspace named "CONTROL". Each workspace pictogram shows the general organization of display objects within the respective workspace. Workspace pictogram **102**, for example, includes window pictogram **104**, and the user can, by an appropriate sequence of signals, obtain more information about the contents of the window corresponding to pictogram **104** or any other display object within overview **100**.

FIG. **6** shows a sequence of steps for entering overview **100** which can be understood with reference to FIG. **5**. The sequence begins in box **120** with the step of providing inactive display features of overview **100** such as the background pattern and title **106**. The title in FIG. **5** is "Overview of rooms", a title which includes the word ROOMS, a trademark of Xerox Corporation used in connection with one implementation of the present invention. The step in box **122** provides a number of display features of overview **100** which, although independent of the currently existing workspaces and their contents, are display tools for facilitating user actions, such as buttons **108**, **110** and **112** and prompt window **114**. The user may use buttons **108**, **110** and **112** to save, restore and augment operations on a group of workspaces, and may receive prompt messages through prompt window **114**. These and other display tools of overview **100** are discussed in more detail below.

The sequence of FIG. **6** continues with the layout of the workspace pictograms, in box **124**. In this step, the system goes through the existing workspaces and determines how they should be laid out on the display. A position and size may be assigned to each of the workspaces so that the workspace pictograms will be displayed in a sequence, such as the alphabetical order shown in FIG. **5**.

The step in box **126** continues by generating the detail for each workspace pictogram. This step may involve retrieving data from the placements associated with each workspace about the position and size of each display object within that workspace. The display system object linked to each placement could also be accessed to retrieve data about the contents of the respective display object, in which case the display object pictogram could include more information about the contents. Rather than accessing the placements and the display system objects to provide each pictogram every time the overview is displayed, however, this step may

involve determining whether a given workspace has changed since the overview was last displayed. If not, the previous pictogram can be retrieved from an overview cache saving the previously displayed pictograms.

When the pictograms have been laid out and detailed, the step in box **128** switches the system into an overview interactive mode, in which the user inputs are handled by procedures appropriate to the overview rather than to the underlying window system. In effect, the window system enters a special state with a special set of display objects and with special procedures to implement the overview.

The manner in which inputs are handled in the overview interactive mode is described in greater detail below, but the user is able to provide sequences of inputs which, for example, cause the system to leave the overview and enter a selected workspace or which cause the respective display object of a selected display object pictogram to appear at a position and size determined by its placement, showing its current contents. Thus the overview interactive mode facilitates user navigation by permitting the user to move to any workspace or to find any desired display object.

FIG. **7** shows a short sequence of steps for leaving the overview. In box **130**, the user signals the system to enter one of the workspaces. Then, in box **132**, the overview display objects are removed from the display and, in box **134**, the system enters the selected workspace. As discussed below, it is possible to exit the overview in this manner because the overview display may be kept current in response to every user signal.

5. Display Object Transfer and Workspace Inclusions. Another aspect of the invention is based on the recognition that the user often needs to move, copy or otherwise transfer a display object from one workspace to another. Conventional techniques of transferring display objects rely on simultaneous display of the source and destination of a transfer operation so that the user can indicate both, but two workspaces are not typically displayed simultaneously. Furthermore, since each display object is a result of the presentation of its contents in accordance with a given placement and since that placement is linked to a given workspace, it is not really possible to transfer a display object from one workspace to another. This aspect of the invention is based on the discovery of a number of techniques which permit the apparent transfer of display objects between workspaces.

Some techniques for the apparent transfer of display objects between workspaces involve the creation of a new placement linking the same display system object to the transferee workspace. For example, any pictogram in overview **100** may be selected and then moved or copied to another workspace. The move or copy operation includes creating a new placement linking that display object to the transferee workspace and including the same display characteristics as the existing placement linking it to the transferor workspace. Additionally, in a move operation, the existing placement is also deleted. The pictograms are then changed in accordance with the changed placements, resulting in a new display object in the transferee workspace which has the same display characteristics as the display object in the transferor workspace. Therefore, it appears to the user that the display object has been moved or copied.

FIG. **5** also illustrates another technique according to the invention for the apparent transfer of display objects between workspaces. Pictogram **102**, labeled "CON-

TROL", includes window pictogram **104** and a number of other pictograms, each representing a window or other display object. Pictogram **102** represents a special workspace, referred to as a control panel, which includes a number of display objects which are useful in many other workspaces. Control panel boundary **116**, which may itself be a window, provides a visual cue identifying the control panel workspace. As shown in FIG. **5**, boundary **116** and the other display objects in pictogram **102** appear in nearly all the other currently existing workspaces. This result is obtained by actually including the control panel workspace in the other workspaces in accordance with the invention, so that the switch from a first workspace which includes the control panel to a second appears to transfer each of the display objects in the control panel from the first workspace to the second. Because the control panel workspace represented by pictogram **102** is included in other workspaces, it can also be used to transfer display objects into the workspaces which include it. In other words, any display object which is transferred into the control panel will simultaneously be transferred into each of the workspaces which includes the control panel.

A workspace may be invisible even when displayed, so that a workspace may include several other workspaces as long as their display objects do not conflict, either with display objects of other included workspaces or with display objects of the including workspace. A conflict could occur, for example, if two or more of the workspaces include placements linking them to the same display system object, in which case one placement might clobber the other one, preventing it from presenting a display object. Some means should be provided to resolve any such conflicts and to avoid a cyclic relation in which two workspaces include each other. Other than that, few constraints on the inclusion of workspaces within workspaces are necessary.

FIG. **8** illustrates schematically the features of the data structure which permit inclusion of one workspace within another. Workspace data structure **140** includes the information necessary to generate the mail workspace, represented by pictogram **118** in FIG. **5**. Workspace data structure **142** similarly includes the information for the control panel, represented by pictogram **102**. Inclusion **144** is a workspace inclusion data structure which links data structures **140** and **142** so that the control panel is included in the mail workspace display. This means that boundary **116**, the window represented by pictogram **104** and the other display objects represented in pictogram **102** are included in the mail workspace display, and they all appear at the same position and size as in the control panel.

Rather than being included in a subset of the other workspaces, a workspace could be included in all the other workspaces, in which case that workspace could be thought of as the user's pockets, a workspace which goes with the user into any other workspace. The display objects included in the pockets are displayed at the same position and size in every workspace. The user can use a special sequence of user inputs to transfer a display object into or out of the pockets without going to the overview. When the user invokes an operation transferring a display object into or out of the pockets, the system creates or deletes the placement linking the corresponding display system object to the pockets workspace. As discussed below, the technique for including the pockets in the other workspaces may differ from the inclusion technique shown in FIG. **8**, and may make use of the workspace leaving step in box **66** in FIG. **3** and the workspace entry step in box **82** in FIG. **4**.

Another technique for transferring display objects from one workspace to another also makes use of the steps in boxes **66** and **82**. As described above, those steps involve operations performed whenever the user leaves or enters a given workspace. If the user provides a sequence of signals indicating that display objects are to be moved or copied from the workspace being left into the workspace being entered, the user is given an opportunity to designate which display objects are to be moved or copied, such display objects being referred to as "baggage". If a display object is being moved or copied, the procedures in box **66** include creating a new placement to ink the corresponding display system object to the workspace being entered, after which the placement linking it to the previous workspace is deleted if the display object is being moved. Then, the procedures in box **82** include linking the new placements to the workspace being entered so that the display objects in the baggage are displayed at the same position and size as in the previous workspace.

6. Workspace Manipulation. Another aspect of the invention is based on the recognition that the user must be able to create, delete and otherwise modify workspaces and modify their contents. The invention includes a number of techniques for solving this problem. Some of those techniques use the overview, in which a display object can be deleted from one workspace or from all workspaces containing it, and in which an entire workspace can be deleted or copied. In addition, the user can edit a description of a workspace from the overview or within the workspace with an appropriate sequence of signals. This aspect of the invention is further based on the discovery of techniques which permit treatment of a group or suite of workspaces as a distinct data structure. This suite of workspaces can be made available to other users, as by storing it on a server, and another user can then add it to an existing set of workspaces through a process called augmenting.

FIG. **9** shows a sequence of steps implementing these techniques. In box **150**, an expert or other user creates a suite of workspaces which are useful for a set of tasks. These workspaces may be suitable, for example, for a novice user of workspaces who needs a basic set of workspaces. Or the workspaces could be suitable for a specialist in a given field who needed a set of workspaces for certain specialized tasks. The creator then invokes a save operation on the suite of workspaces through an appropriate sequence of signals.

The save operation includes loading data relating to display system objects into a file, in box **152**. The display system objects for which data is loaded are those which correspond to display objects in the suite of workspaces being saved, and the data loaded about each display system object will depend on the type of display system object, as discussed in more detail below. Next, the data structures of the workspaces themselves are loaded, in box **154**. The data structure of each workspace is modified so that references to display system objects refer to the display system object as stored in the file, not as it existed in the display system. When the file has been loaded in this manner, it is sent to a file server or other appropriate storage medium in box **156**.

The file may remain on the file server for an indeterminate length of time, as indicated by the dashed line after box **156**. Then, at some point, a user accesses it, in box **158**. The user invokes an operation which recreates the contents of the file. In box **160**, the display system objects are recreated on the display system, and are directed to provide the corresponding display objects to the hiding place, so that those display objects are not displayed. Then, in box **162**, the workspaces themselves are recreated, and the handles of the recreated display system objects in the display system are inserted into the workspace data structures. The user will typically access the file from the overview, so that the overview is updated in box **164**, permitting the user to enter one of the newly added workspaces or perform overview operations.

The technique of FIG. **9** can be used for a number of purposes, including application delivery. As described in greater detail below, another aspect of the invention is to provide a user interface for that purpose.

The various aspects of the invention may be implemented in numerous ways. We will first examine data structures which provide workspaces, and from that continue to leaving and entering a workspace and other procedures; the overview; and saving, restoring and augmenting suites of workspaces.

C. Data Structures

As described above, one aspect of the invention involves implementing workspaces with a preexisting display system such as a conventional window system. It would also be possible, of course, to implement the invention by creating an entirely new display system. The following description focuses on that part of the data structure which must be added to an underlying window system, whether conventional or specially created, in order to implement the invention.

FIGS. **2** and **8**, discussed above, show schematic data structures which include workspace data structures, placements and inclusions. FIG. **10** shows an illustrative overall data structure **170** which illustrates these features according to one implementation of the invention. In FIG. **10**, subsidiary data structures are shown to the right of a line extending downward from the data structure which includes them. Overall data structure **170** thus includes subsidiary data structures **172**, **174** and **176** for workspace A, workspace B, and workspace N, respectively, as well as others not shown.

Workspace data structure **172** for workspace A is shown in more detail than the other workspace data structures, although each workspace data structure includes the same basic data components. Name **180** is the name of the workspace which is used in creating the overview, as shown in FIG. **5**, and which may also serve as the workspace handle for accessing the workspace data structure.

Each workspace data structure may include one or more placements, an example being placement **181**, designated placement A1 because it is the first placement in the data structure of workspace A. Placement **181** itself includes several data components, including display system object handle **182** which can be used to access the corresponding display system object and which therefore links it to placement **181** and hence to workspace data structure **172**. Handle **182** could be a name or number or any other unique identifier of the corresponding display system object or it could be the entire display system object itself. If an identifier, the handle can be provided to the display system for access, and a command provided with the handle will determine the manner in which the display system object responds. Placement **181** also includes position and size data **183** which defines the position and size of the corresponding display object and which therefore indicates the spatial display relationship of that display object to other display objects corresponding to other placements.

Placement **181** includes miscellaneous data components **184** which define other display characteristics of the display object. For example, miscellaneous data components **184** may include information about the drop shadow, such as its width and darkness, and an indication of whether the display object is in shrunken form, such as an icon, and, if so, the position of the icon. If a display object may be made to disappear and come back onto the display or if it can include features which move or are stationary, appropriate data to indicate its present state can be included in miscellaneous data components **184**.

Each workspace data structure may also include one or more inclusions, an example being inclusion **185**, designated inclusion A1 because it is the first inclusion in the data structure of workspace A. Inclusion **185** itself includes a number of data components, including workspace handle **186** and miscellaneous data components **187**. Workspace handle **186** is used to access the included workspace, and may be the workspace's name or a pointer to the workspace data structure. Miscellaneous data components **187** for an inclusion define other display characteristics of the included workspace. For example, data may be included indicating whether the included workspace's background appears in the workspace which includes it and indicating whether the included workspace is offset in relation to the workspace which includes it, so that the display objects it includes may not appear in the same position in each of the workspaces which include that workspace.

Each workspace data structure also includes miscellaneous data components **188**, such as background specifications and procedures to be performed in leaving and entering that workspace. In general, miscellaneous data components **188** define all the other variable features of the workspace. Some of these features are used to distinguish that workspace from other workspaces, such as the background; others may provide procedures or data useful during task switching, such as the position at which a back door to the previous workspace will be displayed. Some of these components are discussed below in relation to Table I.

FIG. **10** also shows a few of the data components in workspace data structure **174** for workspace B, illustrating two ways in which workspaces may share a tool. Placement **190**, designated placement B1, includes display system object handle **192**. As shown, handle **192** has the value X, the same value as handle **182** in placement **181** in workspace data structure **172**. Therefore, placements A1 and B1 link the same display system object to workspaces A and B, respectively. The display characteristics of the tool provided by the display system object may be different in the two workspaces, but it will be available in both. Similarly, inclusion **194**, designated inclusion B1, includes workspace handle **196**. As shown, workspace handle **196** has the value N, the same value as workspace handle **186** in inclusion **185**. Therefore, inclusions A1 and B1 include the workspace N in workspaces A and B, respectively. The display characteristics of the display objects in workspace

N will generally be the same when they are presented in workspaces A and B.

TABLE I

```
(WS.WORKSPACEA  (BACKGROUND  (FRAME  (SHADE <shade>)
                                      (FRAME.WIDTH <width>))
                               (TEXT    (STRING "SPACE A")
                                        (FONT <font>)
                                        (POSITION <x,y>)
                                        (DROP.SHADOW
                                         <boolean>)))
   ((PLACEMENT  (OBJECTX  (POSITION <x,y>, SIZE <h,w>)
                          (DROP.SHADOW.DATA <width,darkness>)
                          (SHRINKING.DATA <boolean,location>))
    (PLACEMENT  (OBJECTY  (POSITION <x,y>, SIZE <h,w>)
    (INCLUSIONN)
    (INCLUSIONP)
    (PROPERTIES <functions>))
(WS.WORKSPACEB  (BACKGROUND  (TEXT  (STRING "SPACE B")
                                    (FONT <font>)
                                    (POSITION <x,y>)
                                    (DROP.SHADOW
                                     <boolean>)))
   ((PLACEMENT  (OBJECTX  (POSITION <x,y>, SIZE <h,w>)
                          (DROP.SHADOW.DATA <width,darkness>)
                          [SHRINKING.DATA <boolean,location>))
    (PLACEMENT  (OBJECTZ  (POSITION <x,y>, SIZE <h,w>)
    (INCLUSIONN)
    (INCLUSIONQ)
    (PROPERTIES <functions>))
(WS.WORKSPACEN  (IF          (TEXT  (STRING "SPACE N")
                                    (FONT <font>)
                                    (POSITION <x,y>)
                                    (DROP.SHADOW
                                     <boolean>)))
   ((PLACEMENT  (OBJECTV  (POSITION <x,y>, SIZE <h,w>)
                          (DROP.SHADOW.DATA <width,darkness>)
                          (SHRINKING.DATA <boolean,location>))
    (PROPERTIES <functions>))
```

Table I shows in text form a pseudo-code data structure corresponding to overall data structure **170** in FIG. **10**. The data structure in Table I includes three workspace data structures, each beginning with "WS.WORKSPACE" followed by the name of the workspace, A, B or N. After the name is the background specification, part of the miscellaneous data concerning the display characteristics of the workspace. The background of workspace A includes a frame, which has a specified shade and width. It also has the title "Space A" with a specified font, position and drop shadow. The background of workspace B has a title but no frame. The background specification of workspace N is preceded by the conditional "IF" meaning that it has a title only when it is displayed on its own and not when displayed as an included workspace.

After the background specification of each workspace appear its placements, each with the handle of a display system object and the display characteristics of the corresponding display object within that workspace. The display characteristics include the position and size of the display object, each of which may be specified with a pair of numbers, position by the left and bottom coordinates and size by the width and height. Then follow the drop shadow data and shrinking data, if any, which may include the left and bottom coordinates of the shrunken form of the display object.

After the placements are the inclusions, each including a workspace handle. Then follow the properties, which may be miscellaneous procedures to be called upon entering or leaving the workspace, and which may be included in the procedures in box **66** in FIG. **3** and box **82** in FIG. **4**.

Some of the display presentation characteristics in overall data structure **170** in FIG. **10** correspond to data in display system objects in the underlying display system. For example, position and size data **183** and miscellaneous data components **184** ordinarily correspond to data used by object X to provide its display object when workspace A is displayed. Because these display presentation characteristics are included in the placements, they can be different for each workspace which has a placement linking to object X. The data in the object itself may be changed or lost, however, if it presents a display object with different display characteristics in another workspace, depending on the display system's operations. As discussed below, the display presentation characteristics are provided to the object from the placement which links that object to a workspace being entered, with the result that the object presents a display object in accordance with its placement, not with its previous presentation.

The simplicity of overall data structure **170**, as shown in FIG. **10** and Table I, makes it easy for a user to edit each workspace data structure and permits compact storage of a suite of workspaces, features of the invention discussed below. As we will now see, however, this simplicity conceals a number of relatively complicated procedures which are part of this implementation of the invention.

D. Procedures

As described above, the invention solves a number of user interface problems, several of which relate to task switching. Therefore, procedures are necessary to set up an underlying display system for task switching and also to perform task switching when requested by the user.

FIG. **11** shows how the relevant states (shown as ellipses) and procedures (shown as rectangles) of one implementation may be analyzed, with the transitions between the states and procedures resulting from user commands relating to task switching. Initially, the system setup procedure 200 prepares the system to display an initial workspace and to perform task switching when requested. Upon completion, the system goes through a transition to its underlying display system operation 202, in which the system responds to a wide variety of user commands. But when the user provides a command requesting that another workspace or the overview be displayed, the system performs an exit workspace procedure 204 to exit the currently displayed workspace. Then, if the user request is for another workspace, the system performs an enter workspace procedure 206 to display the requested workspace, after which it returns to display system operations 202.

The description in this section focuses on system setup 200, exit workspace 204 and enter workspace 206. FIG. 11 also shows, however, several procedures which will be discussed in the next section in relation to the overview, through which the user can obtain information to assist in task switching. After exit workspace procedure 204, if the user requested the overview, enter overview procedure 210 is performed, resulting in an overview display, an example of which was described above in relation to FIG. 5. Then the system enters overview interface mode 212, in which the system responds to various user commands related to the overview. When the user provides a command to enter a workspace or to restore or augment with a suite of workspaces from a file, the system performs exit overview procedure 214. If entering a workspace, the system then performs enter workspace procedure 206 to display the requested workspace. It then returns to display system operations 202. But if restoring or augmenting, the system performs enter overview procedure 210 and then returns to overview interface mode 212.

We now consider in more detail some of the procedures in FIG. 11.

1. System Setup. A central objective of system setup procedure 200 is to permit rapid, effective task switching by the user once the system is set up. A small number of signals from the user should suffice to invoke a task switch, and once invoked, the task switch should be performed rapidly. But between task switches, display system operation 202 should continue in its usual fashion, displaying the current workspace.

FIG. 12 shows a technique for setting up an underlying window system for workspace operations, including workspace display and task switching. Prior to setup, the window system will include some combination of existing display system objects, each providing a window, and the step in box 220 initializes the window system in preparation for beginning workspace operations. This step may involve creating additional display system objects or modifying existing objects to support workspace operations. It may also involve modifying the window management software to include procedures for responding to commands from the workspace system. For example, if a user invokes a workspace system procedure which provides the handle of a display system object and a command indicating an operation to be performed in relation to that display system object, the window system would execute such a procedure to perform the operation and return the results to the workspace system procedure.

The steps in boxes 222 and 224 together create an overall data structure which the user can modify during subsequent operations to include the workspaces appropriate to the tasks being performed. In box 222, the setup procedure creates a data structure for an initial workspace which will be displayed when display system operation 202 begins. This initial workspace's data structure will have default values for its background and properties, and will begin with no placements or inclusions. In box 224, the setup procedure creates a placement for each of the existing display objects, linking the corresponding display system object to the initial workspace's data structure.

The final steps in FIG. 12 prepare the system to receive the relevant user commands. The window system's user interface will include some mechanism for receiving user commands, and the step in box 226 adds special commands relating to task switching to that mechanism. For example, if the window system has a background menu which the user can view by selecting a location in the display background, special commands can be added to the background menu. The menu may include a command which, when selected, provides a submenu enabling the user to select any existing workspace or to select the creation of a new workspace. The menu may also include an "Overview" command which, when selected in one way, leads to entering the overview, but when selected in another way, enables the user to pick a display object up and put it in the pockets or to put down a display object which was previously in the pockets.

When the special commands have been set up in box 226, the system continues to display system operation 202, with further workspace operations occurring only when a user command requesting such operations is received. We turn now to examine exit workspace procedure 204, a workspace operation by which the user may leave the initial workspace or any other workspace.

2. Exit Workspace. A user may invoke exit workspace procedure 204 in several ways, but the procedure is substantially the same regardless of how invoked, and follows the general sequence described above in relation to FIG. 3. One of its purposes is to update the current workspace's data structure so that the next time the user enters the workspace being exited, it will appear much the same as when exited. This purpose is served by storing data in placements, as described above in relation to box 62 in FIG. 3.

A number of steps are taken in updating the workspace data structure: If a new window or other display object has been created, a placement is created linking the underlying display system object to the current workspace. If a window in the currently displayed workspace has been deleted, the placement which linked the corresponding display system object to that workspace is deleted. The display characteristics in the placement of each displayed window are updated, and the placements are reordered according to their stacking in the current display.

Inclusions present some special problems in updating the workspace data structure. Even though a window in an included workspace has been deleted from the display, it may be inappropriate to delete it from the included workspace, because it may be needed in other workspaces which include that workspace. Similarly, if a window is in the currently displayed workspace and in one of its included workspaces or if a window is in more than one of the included workspaces, the only placement which should be updated is the one corresponding to the window as actually displayed. As will be seen below, one way of resolving these problems is to delete placements only from the currently displayed workspace and to update only one placement for a given application, the one responsible for the display object in the current workspace.

FIG. **13** illustrates general steps of a procedure for exiting a workspace. The procedure of FIG. **13** begins when the user signals for an exit from the currently displayed workspace, in box **240**. A number of signal sequences indicating an exit from the currently displayed workspace are described below in relation to FIG. **14**, together with related preliminary steps.

The workspace exit procedure requires certain information from the display system. In box **242**, the procedure retrieves the current list of displayed windows to assist in updating the placements. At the same time, the procedure may retrieve other data it requires, including the handle of the currently displayed workspace, which it will use to access that workspace's data structure. Then, in box **244**, it creates a list of displayed workspaces, including the current workspace and the workspaces included in it, as described below in relation to FIGS. **15**A and **15**B. Then, it uses the list of workspaces and the list of windows to create a list of placements which control currently displayed windows, in box **246**, as described below in relation to FIG. **16**. The controlling placements are then examined to determine which placements require updating.

The test in box **248** begins this process by determining whether any of the controlling placements remain to be examined. If so, the next unexamined placement is accessed in box **250**. The placement list contains sufficient data to access the placement, and may, for example, include the handle of the display system object and the handle or other identifier of the workspace. The placement may then be accessed by accessing that workspace's data structure and finding a placement with a matching object handle.

Once the placement has been accessed, it is compared with the handles of the currently displayed windows in the window list, in box **252**. If it matches one of the windows, that window is marked as having been matched in box **254**. Since the placement is one of the controlling placements, this must be the window it controls. Then, in box **256**, the contents of the placement are compared with the current display characteristics of the window to determine whether any changes have occurred since the workspace was entered. If so, the placement is updated in box **258** to reflect the changes and the workspace which contains that placement is marked in box **260** to indicate that it contents are changed, so that its pictogram in the overview must be modified next time the overview is entered. Since the overview display, as shown in FIG. **5**, requires a substantial amount of computation, it is advantageous to cache the overview contents during those periods of time when it is not displayed. It is also advantageous to recompute the pictogram of a workspace only when necessary, since recomputing a workspace's pictogram involves recomputing the pictograms of all the workspaces which include it. Therefore, a workspace's pictogram is recomputed only when the workspace is marked changed. The workspace may be marked changed by inserting an indication in the overview cache that the workspace's pictogram must be recreated

next time the overview is entered. After completing this step, the procedure returns to the test in box **248** to determine whether unexamined controlling placements remain.

If, on the other hand, the test in box **252** determines that the controlling placement being examined does not match any of the currently displayed windows, the display object corresponding to that placement must have been deleted since the current workspace was entered. The test in box **262** determines whether the placement which does not match is in the currently displayed workspace, in which case that placement is deleted in box **264**. If the placement is not in the currently displayed workspace, it must be in one of its included workspaces, in which case the placement is not deleted, on the theory that the user probably did not intend to delete a window from the other workspaces which might contain it. If a placement was deleted, the current workspace is marked changed in box **260**, as above, before returning to the test in box **248** for further placements to be examined.

When all the controlling placements have been examined, the test in box **270** determines whether the window list contains any unmatched windows. If so, those windows have been created since the current workspace was entered, and placements do not yet exist for them. The step in box **272** creates a placement linking the underlying display system object of each unmatched window to the current workspace, and including the display presentation characteristics of that window as currently displayed. The current workspace is then marked changed in box **274**.

At this point the procedure begins to go through the workspaces on the workspace list to reorder the placements if necessary. The test in box **276** determines whether unvisited workspaces remain on the list to be examined and, if not, the step in box **278** proceeds to clear the display by moving all the current display objects to the hiding place. If, on the other hand, workspaces remain to be visited, the next workspace is accessed in box **280** and marked visited in box **282**. The test in box **284** determines whether that workspace has already been marked changed, in which case it is necessary to reorder its placements. If not, the test in box **286** determines whether it is necessary to reorder the placements anyway because the order has changed, as described below in relation to FIG. **17**. If the order has changed, the current workspace is marked changed in the overview cache, in box **288**. The placements are then reordered, in box **290**, one technique for which is also shown in FIG. **17**. When any necessary reordering of this workspace is completed, the procedure returns to repeat the test in box **276**.

As noted above, when all workspaces have been visited, the display is cleared in box **278**. This may be done by giving a command which causes the window system to change each display system object so that all the display objects are made invisible, as by providing them to the hiding place. Another step taken at this time or earlier is to store a value indicating that the workspace being exited is the previous workspace. Other procedures which are part of workspace leaving procedures **66** in FIG. **3** are discussed in more detail below.

FIG. **14** shows exemplary signal sequences by which the user may signal a workspace exit, corresponding to box **240** in FIG. **13**. The simplest is to select a door or back door, in box **300**. Other sequences begin in box **302** with the selection of the background of the currently displayed workspace, in which case the window system displays a pop up menu in box **304**. The user may then select the "Overview" command on the pop up menu, in box **306**. The user may also select the "Go to Another Workspace" command, in box **308** or may select a special type of door labeled "Go To", in box **310**; in either case, the system displays a pop up menu with the names of all existing workspaces and other options in box **312**, and the user may select a workspace to enter in box **314**. All these sequences of use signals take place within the window system, but each leads to a command which begins exit workspace procedure **204**, in box **316**. The sequence of signals which invokes the exit workspace procedure may involve certain data which is stored at the beginning of the procedure. FIG. **14** shows an example in box **318**, with the procedure noting the type of door, whether an ordinary door or a back door, to determine whether it is necessary to add a back door to the next workspace entered. Similarly, the procedure would store the name or handle of the next workspace to be entered if the sequence of signals indicated that another workspace should be entered.

FIG. **15A** and **15B** shows a routine for creating a list of workspaces in box **244** in FIG. **13**. This list and the placement list created in box **246** provide the information with which the routine of FIG. **13** accesses the actual placements and workspace data structures in the process of updating and reordering the placements. These lists could be created in a multitude of ways, but the routine in FIGS. **15A** and **15B** orders the workspaces such that the list of controlling placements created by the routine of FIG. **16** can be more easily created. The routines of FIGS. **15A**, **15B** and **16** rely on the ordering of the placements and inclusions within each workspace's data structure. It is assumed that the placements are ordered in the order in which the corresponding window is moved from the hiding place to the display, so that the last placement in each workspace corresponds to the topmost window in that workspace. The inclusions are similarly ordered in the order in which their placements are moved to the display, so that the last inclusion in each workspace corresponds to the topmost inclusion. The ordering of either the placements or the inclusions or both could be reversed without significantly changing the routines of FIGS. **15A**, **15B** and **16**.

The main routine of FIG. **15A** creates a list in which the workspaces are listed in the reverse order in which their placements are moved to the display, or from top to bottom. The step in box **330** sets up and initializes two lists, one the L list and the other the Seen list. The step in box **332** calls a recursive procedure ExitProc and provides the handle of the current workspace as well as the Seen and L lists. Upon receiving these lists back, the step in box **334** again calls ExitProc, this time providing the handle of the pockets room and the lists. Upon receiving the L list back, the step in box **336** reverses the order of the workspaces in the L list and returns the reversed list, which will have the pockets room as its first member.

ExitProc, as shown in FIG. **15B**, begins with a call in box **340** which includes the handle of a workspace, WS, as well as the Seen and L lists. The test in box **342** determines whether WS is in the Seen list. If not, WS has not yet been processed. The step in box **344** adds WS to the Seen list and the step in box **346** uses WS to access that workspace's data structure. The test in box **348** determines whether inclusions remain to be examined in the data structure. If so, the next inclusion is accessed in box **350** and its handle is provided in a recursive call of ExitProc. When the test in box **348** determines that all the inclusions in WS have been examined, WS is added to the end of the L list in box **354** and the L and Seen lists are returned in box **356**. The L and Seen lists would have been returned immediately had the test in box **342** determined that WS was in the Seen list.

The workspace list created by the routine of FIGS. **15A** and **15B**, in addition to keeping the pockets at the top of the list, takes care of some potential problems. If two workspaces include each other, the routine will not cycle, but will take only one instance of each workspace, the instance responsible for displaying the placements in that workspace. Also, if a given workspace is included in more than one of the other workspaces included in the current workspace, only one instance of that workspace will be on the list, again the instance responsible for displaying the placements in that workspace. Because these problems are avoided, the preparation of the controlling placement list is simplified.

The routine of FIG. **16** creates a list of controlling placements as of the time the current workspace was entered. It begins by creating and initializing the placement list in box **370**. The routine then goes to the top workspace on the workspace list or L list created by the routine of FIGS. **15A** and **15B**, in box **372**, and proceeds toward the beginning of that list in subsequent operations. As noted above, if a pockets room exists, it will be the top workspace.

The test in box **376** determines whether the routine has reached the bottom workspace on the list. If not, workspaces remain to be examined, and the routine takes the next workspace's handle from the list in box **378** and uses it to access that workspace's data structure in box **380**. The routine retrieves the handles from the placements in box **382** and creates a temporary list, TempList, listing the placements in reverse order. The test in box **384** determines whether any placements on TempList remain to be examined. If so, the handle in the next unexamined placement is accessed in box **386** and compared with the handles already on the list by the test in box **388**. If the handle is not yet on the list, it is added at the end of the list, in box **390**, and the routine routines to the test in box **384** for further placements. For purposes of subsequent routines it is useful for each entry in the controlling placement list to include the handle or other indicator of the workspace in which each placement is first found, and this can be done in box **390**.

When all the placements in a workspace have been examined in this manner, the routine returns to the test of box **376**. When the last workspace has been examined, the test in box **376** determines that no workspaces remain, and the placement list is complete, as indicated in box **396**. The controlling placement list contains only one entry with each placement handle, and that entry indicates the handle of the workspace which includes the placement controlling the corresponding display object when the current workspace was entered. It is this placement which is subsequently updated in box **258** in FIG. **13**, if necessary.

The controlling placement list created in FIG. **16** also plays a role in determining whether the placements in a given workspace are in the same order as when the current workspace was entered, in box **286** in FIG. **13**. FIG. **17** shows a routine for testing whether the placement order has changed in a way necessitating the reordering of the placements in box **290**.

The routine of FIG. **17** begins by creating a temporary list of the controlling placements which are in the workspace being examined, in box **400**. These placements may be obtained from the controlling placement list created by the routine of FIG. **16**, and should have the same order in the temporary list as they have in the controlling placement list. For each controlling placement on this temporary list, the routine retrieves the position of the corresponding window on the window list, in box **402**. This can be done by finding the window list entry with a matching handle.

The routine then proceeds through the temporary list, with the test in box **404** determining whether any placements remain to be examined. If so, the next unexamined placement on the temporary list is taken in box **406**. The test in box **408** then determines whether there are any uncompared placements after this placement. If so, the next uncompared subsequent placement is taken in box **410**. The test in box **412** compares the window list positions of this uncompared placement with the placement being examined. If the position of the placement being examined is further down in the window list than that of the uncompared placement, they are not in the same order they were in when the current workspace was entered. It may not be necessary to reorder the placements, however, if the placements which are out of order do not overlap, as determined by the test in box **414**. If reordering is not necessary, the test in box **408** is repeated for subsequent uncompared placements on the temporary list.

The routine continues through subsequent uncompared placements until all have been compared. Then, the routine returns to the test of box **404** to determine whether further placements remain to be examined. If not, the routine has gone through the entire list without finding it necessary to reorder, so that the result of the test in box **286** in FIG. **13** is that the placements are in the same order, as indicated in box **416**.

If reordering is necessary, either because of the test in box **414** in FIG. **17** or because of the test in box **284** in FIG. **13**, reordering begins with the top placement in the temporary list. If the routine comes directly from box **284**, it is therefore necessary to create the temporary list as in boxes **400** and **402** before proceeding with this step. The test in box **432** determines whether placements remain on the temporary list. If so, the next remaining placement is taken in box **434**, and the routine also finds the lowest list position of all the remaining placements, in box **436**. If the test in box **438** determines that the placement taken in box **434** has the lowest list position, then this placement is correctly ordered. Otherwise, the placement with the lowest list position is exchanged with this placement in box **440**, and the routine proceeds to the next remaining placement. When all the placements have been examined in this manner, the routine of FIG. **17** is complete.

When the routine of FIG. **13** has been completed, exit workspace procedure **204** performs any additional workspace exit procedures which are appropriate. Some of these procedures may be specific to the workspace being left, as in box **66** in FIG. **3**. Each of these exit procedures is typically paired with an entry procedure in box **82** in FIG. **4**, with the entry procedure setting up the system to operate in a particular manner while it is the current workspace and the exit procedure resetting the system to a neutral state in which it is ready to enter any workspace, the current workspace returning to its virtual state until it is next entered.

Some of the entry and exit procedures could, for example, determine how display objects appear within a workspace. An entry procedure could set up the workspace so that windows will be tiled in columns or will appear in fixed positions, with the paired exit procedure returning the window system to display windows in an overlapping mode. An entry procedure could change a connected directory, with the paired exit procedure restoring the previous connected directory. An entry procedure could retrieve a data structure specific to that workspace which supports particular operations in the workspace, with the paired exit procedure storing that data for subsequent retrieval during the next entry procedure in that workspace. An entry procedure could retrieve a variable to be used in the workspace, such as a handle for an input/output device such as a printer, with the paired exit procedure returning the system to a default variable.

Entry and exit procedures can also be used in implementing baggage features. For example, baggage operations can be invoked by a special sequence of signals from the user which also invoke the workspace exit procedure. Before proceeding with workspace exit, the baggage operations could provide a prompt asking the user to indicate the windows to be included in baggage, and the user could select each window, indicating whether it should be moved or copied into the next workspace entered. The workspace exit procedures could then store the data necessary to perform the requested move and copy operations upon entering the next workspace, and the workspace entry procedures could retrieve that data and delete and create placements accordingly.

At the completion of exit workspace procedure **204**, the system is ready to enter another workspace or the overview. We turn now to enter workspace procedure **206**. 3. Enter Workspace. Like exit workspace procedure **204**, enter workspace procedure **206** may be invoked in a number of ways, each leading to substantially the same steps. One major objective of enter workspace procedure **206** is to produce a display closely resembling the display which existed when the user last exited from the workspace being entered. The same windows should be present, displayed in the same way and with the same apparent stacking order.

The implementation of exit workspace procedure **204** described above updates the workspaces data structure to include data necessary for regenerating substantially the same display at a later time. Enter workspace procedure **206**, in regenerating the display, must reflect to an extent the steps taken in exit workspace procedure **204**. It does so in a manner which also follows the general sequence in FIG. **4**.

FIGS. **18**A and **18**B illustrate a procedure for entering a workspace which reflects the steps taken in the procedure of FIG. **13**. The basic strategy of FIGS. **18**A and **18**B is to walk through the workspace data structures, displaying the window corresponding to each controlling placement from the bottom to the top.

The enter workspace procedure of FIG. **18**A begins in box **450** when the exit workspace procedure is completed in response to a command to enter another workspace or when the overview is exited to enter a workspace. In either case, the identifier of a workspace to be entered will be provided, and certain other data will have been stored in exiting the previous workspace.

The step in box **452** retrieves some of that data and takes preparatory steps based on it, such as determining whether the workspace being entered is different than the previous workspace so that a back door should be created, in which case a display system object for a back door is set up and linked by a placement to the workspace being entered. Other workspace entry procedures in box **452** may include creating placements for baggage from the previous workspace and setting up the system to operate in the workspace being entered, as discussed above. A list of workspaces visited during the recursive walk, designated the Seen list, is set empty in box **454**. The step in box **456** then calls the recursive procedure EnterProc, providing the current workspace's handle and the Seen list. Upon receiving the Seen list back, the step in box **457** calls EnterProc, providing the handle of the pockets workspace and the Seen list. Upon completion, the workspace has been entered and display system operations resume in box **458**. The workspace system in effect becomes dormant until the next sequence of user signals invoking workspace operations.

EnterProc procedure in FIG. **18B** begins with a call with the handle of a workspace, WS, and the Seen list. The test in box **561** determines whether WS is in the Seen list. If not, WS is added to the Seen list in box **462** and the corresponding data structure is accessed in box **464**. The background specification from that data structure is accessed in box **466** and used to generate any specified additional background features.

The test in box **468** determines whether any unexamined inclusions remain in the current workspace. If so, the next unexamined inclusion is accessed in box **470**, and EnterProc is recursively called with the workspace handle from that inclusion, in box **471**. Upon completion, the test in box **468** is repeated.

When no more inclusions remain in the current workspace, the test in box **472** determines whether any unexamined placements remain. If so, the next unexamined placement is accessed in box **473**, and its handle is used in box **474** to access the corresponding display system object. The data from the placement is loaded into that display system object in box **476**, and the display system object proceeds to display the appropriate display object with the display characteristics indicated in the placement. This effectively moves the display object back from the hiding place onto the display or otherwise makes it visible and changes its display characteristics in accordance with the placement. This step should be done without interrupting the operations of the display system object, so that continuity is maintained.

When all the placements in the current workspace have been examined, the procedure returns the Seen list, in box **478**. If the test in box **461** determined that WS had already been visited, the procedure would immediately return.

As noted above, enter workspace procedure **206** can occur not only after exit workspace procedure **204** but also after exit overview procedure **214**. Similarly, exit workspace procedure **204** can lead not only to enter workspace procedure **206** but also to enter overview procedure **210**. We turn now to consider the overview-related procedures and other features of the overview in more detail.

E. The Overview

Some features of the overview are discussed above in relation to FIGS. **5**–**7**. FIG. **11** shows the sequence of commands leading to the overview, and FIG. **14** shows a sequence of user signals which result in leaving a workspace and entering the overview.

The overview could be implemented in various ways. For example, the overview can be implemented as a unique workspace which has a unique set of display objects and, unlike the other workspaces, does not appear in the overview. It could also be implemented as a workspace like the other workspaces, so that the display objects in it could be moved and copied to other workspaces. The following description generally is based on the implementation of the overview as a unique workspace whose display objects are based on data stored in an overview cache which contains current versions of the workspace and window pictograms, to save time in entering the overview.

After briefly discussing further details of workspace and window pictograms, we will cover the operations available in overview interface mode **212** in one implementation of the overview according to the invention.

1. Pictograms. The layout and detailing of pictograms is discussed briefly in relation to boxes **124** and **126** in FIG. **6**. FIG. **19** illustrates in more detail the layout and detailing steps of FIG. **6**.

The enter overview procedure of FIG. **19** begins in box **480**, and initial steps as shown in boxes **120** and **122** in FIG. **6** include providing the overview background and title as well as the overview tools. The procedure then accesses the overall data structure which includes all the workspace data structures, in box **482**. The workspaces are listed and counted in box **484**. This list, unlike the workspace list discussed in relation to FIGS. **15A** and **15B**, may be based on alphabetical order, and may be created simply by sorting the overall data structure so that the workspace data structures are ordered alphabetically by workspace name. Then, in step **486**, the sizes and positions of the workspace pictograms are determined based on the number of workspaces. In the example of FIG. **5**, with eleven workspaces, positions and sizes are assigned so that three rows of four workspace pictograms each will fit within the available display area in the appropriate order, so that an area for the twelfth workspace pictogram is open. This corresponds to the layout step in box **124** in FIG. **6**.

The details of each workspace's pictogram may be stored in an overview cache, as mentioned above. Therefore, to obtain the pictogram, the procedure of FIG. **19** checks whether the pictogram in the overview cache is accurate and, if not, recreates the entire pictogram in a manner very similar to the procedure of FIGS. **18A** and **18B**. The test in box **488** determines whether any unexamined workspaces remain on the list of workspaces, and if so the next workspace's data structure is accessed in box **490**. The test in box **492** determines whether the workspace has been changed in a way which will affect the pictogram, testing whether the workspace was marked changed during an execution of the procedure of FIG. **13**. If so, the procedure retrieves the cached pictogram and displays it at the appropriate position and size within the overview in box **494**.

If the test in box **492** determines that the workspace has been changed, the procedure first sets up a blank pictogram with a title, in box **496**. The step in box **500** lists the controlling placements as in FIGS. **15A**, **15B** and **16**. In the process, however, the background of the blank pictogram is painted, as in box **466** in FIG. **18B**.

If the test in box **510** determines that unexamined placements remain on the controlling placement list, the next unexamined placement is accessed in box **512**. It is desirable to include in some of the window pictograms details about the display system objects which provide the corresponding windows, and this requires that the display system objects be accessed. As discussed in more detail below, an access of this nature is outside the normal display system operations, and requires special functions which are tailored to the type of display system object being accessed. A window registration system, discussed in detail below, includes a set of functions for each registered type of display system object, and one function for each type is capable of recognizing whether a given display system object is of that type. In box **514**, the Recognize function for each of the types is called, together with the handle from the placement being examined. If any of the Recognize functions recognizes the display system object, in box **516**, another function for that type, the Present function, is called in box **518**. This Present function is tailored to retrieve from a display system object of that type any information to be displayed in its pictogram. If the display system object is not recognized, however, a blank pictogram is provided, in box **520**.

The step in box **522** then displays the pictogram obtained in accordance with the position and size data in the placement. If the position of the placement is outside the boundaries of the worksapce pictogram created in box **496**, this step may also involve reshaping the workspace pictogram to include a virtual part.

When all the pictograms in the workspace pictogram have been displayed, the procedure returns to the test in box **488**. And when all the workspaces on the alphabetical list have been visited, the overview is complete, and the overview interface mode **212** is entered in box **530**. We turn now to the details of that mode.

2. Overview Interface Mode. When the overview is presented to the user, various operations are available which would be impossible or at least difficult when one of the workspaces is displayed. As noted above, the overview allows the user to navigate from one workspace to any other workspace, and assists the user in selecting a destination by presenting information about each workspace. Furthermore, if workspaces are implemented with a preexisting display system, the overview provides an opportunity to perform a number of operations not available during display system operations, including manipulations of placements, of workspaces and of collections of workspaces.

In one implementation, all of the pictograms are windows of the window system, with the window pictograms being superimposed on the workspace pictograms, and with all of the pictograms being displayed when the overview workspace is displayed. Each of these windows is provided by a corresponding display system object which receives and responds to user signals relating to that window. In this case, the overview interface mode is simply a special case of normal display system operations, and user signals relating to the pictograms and other overview display objects invoke appropriate procedures. The overview could be implemented in a number of other ways, however, and need not be part of normal display system operations.

FIG. **5**, discussed above. shows overview **100**, which includes some additional features. As mentioned immediately above, each workspace pictogram has a background, the background of control panel **102** being closely spaced parallel diagonal lines, for example. Window pictogram **530** and other window pictograms have additional detail based on data retrieved from the underlying display system object by the present function. Horizontally extended workspace pictogram **532** includes, in addition to that part of a workspace which is presented on the display, an additional area which shows a part of window pictogram **534** which extends beyond the displayed part, occupying a virtual part of that workspace. Similarly, vertically extended workspace pictogram **536** includes an additional area which shows a part of window pictogram **538** in a virtual part of the workspace.

Keyboard command buttons **540** provide a variety of overview interface operations. In general, overview **100** is designed to give the user an indication of each available operation and of each change of state which occurs while in overview interface mode. The actual implementation of overview **100** affects the manner in which a user invokes an operation as well as the display features indicating execution of that operation. For example, in one implementation a user selection of one of keyboard command buttons **540** does not directly invoke the corresponding operation, but rather results in a remainder in prompt window **114** of the keyboard sequence to invoke that operation. And whenever that operation is invoked, the corresponding keyboard command button is inverted, as shown for "Edit" button **542**, and remains dark until the operation is completed.

We turn now to consider the operations which correspond to keyboard command buttons **540**.

Some keyboard command buttons correspond to navigational operations. The "Enter" button, for example, corresponds to the basic navigational operation of entering a workspace. Therefore, when the enter operation is invoked and a workspace is selected, an exit overview procedure like that described in relation to FIG. **7** is performed and then an enter workspace procedure as in FIG. **18**.

In order to select a workspace, the user moves a pointer using a mouse or other pointer control device until it points to the workspace pictogram corresponding to the workspace to be selected. Since each workspace pictogram is likely to contain one or more window pictograms, it is necessary to distinguish somehow between a workspace selection and a window selection when the pointer is pointing to a window pictogram. If the mouse has more than one button, one button can be used to indicate selection of the window pictogram and another to indicate selection of the workspace pictogram in which the window pictogram is located. Upon receiving a window pictogram selection, the corresponding placement is accessed based on information in the overview cache which indicates which placement corresponds to each region within each workspace pictogram.

A number of keyboard command buttons **540** correspond to operations which manipulate placements, and a placement to be manipulated is selected by selecting the corresponding window pictogram in the workspace pictogram of the workspace which contains it. The "Move" button corresponds to the operation of moving a placement to a selected location within the same workspace by modifying the placement or from one workspace to another selected workspace by deleting one placement and creating another linked to the other workspace. The "Copy" button with selection of a window pictogram corresponds to the operation of creating another placement linking the same display system object to another selected workspace. The

"Shape" button corresponds to the operation of modifying a placement to a selected size, the size being selected by adjusting an outline of the window using the mouse. The "Delete" button with selection of a window pictogram corresponds to the operation of deleting the corresponding placement.

An operation which manipulates a placement, but which does so to assist navigation, is the expand operation, corresponding to the "Expand" button. The expand operation displays the full size current contents of a selected window at a location on the workspace pictogram to which it is linked by the selected placement. If the expand operation is invoked with selection of a window linked to an included workspace, the current contents are thus displayed full size at a position based on the placement but on the included workspace's pictogram rather than the workspace pictogram in which the selection was made. Since all the windows will be at the hiding place during overview interface mode, the expand operation can be performed by moving the selected window from the hiding place to the workspace pictogram to which it is linked. The expand operation is especially useful in finding a window based on its current contents.

Another placement manipulation operation which may be useful in navigation corresponds to the "Shares" button. This operation, after determining the selected placement, goes through the overview cache and finds all the other placements which contain the same handle. The window pictogram corresponding to each such placement is then made more visible, by blinking or the like, so that the user can identify all the workspaces that share that window.

Some of the workspace manipulation operations correspond to placement manipulation operations. For example, a copy or delete operation can be performed on a selected workspace by copying or deleting that workspace's data structure. In order to copy a workspace, however, it is necessary to assign a different name to the copy, so that the user will be asked to provide a name during the copy operation. The overview will be laid out again to accommodate the copied workspace. The "New" button corresponds to a similar operation which creates a new workspace and asks the user to provide a name. A variable can be set up to provide a default background specification and a list of inclusions that will automatically be included in a new workspace created in this manner. Similarly, the "Rename" button corresponds to an operation which asks the user to provide a new name for an existing workspace.

The "Edit" button corresponds to a workspace manipulation operation which permits the user to edit a workspace's data structure. It does so by displaying a description of the data structure within the corresponding workspace pictogram, as shown in pictogram **550** in FIG. **5**. Pictogram **550** is thus a window in which interactive editing can be done, with the available commands appearing in adjacent edit menu **552**. When editing is completed by an appropriate user signal, the workspace pictogram is generated again in accordance with the changed data structure. More than one workspace could be edited in this manner at a time, so that data could be copied from the description of one workspace's data structure to another's.

The remaining keyboard command buttons correspond to workspace manipulation operations which can assist in navigation and in understanding the connections between workspaces, either through doors or through inclusions. Each connection may be shown by a link which is a line with one end a light circle and the other end a dark circle. The "Doors" button corresponds to an operation which shows where each door in a selected workspace leads, the light circle of each link being at the door and the dark circle being on the workspace pictogram of the workspace to which that door leads. The "Doors to" button corresponds to the converse operation, linking all doors in other workspaces which lead to a selected workspace. The "All doors" button corresponds to an operation which links all doors and their destinations. The "Includes" button corresponds to an operation which links a selected workspace to all workspaces it includes, the light circle being in the including workspace and the dark circle in the included workspace. The "Included in" button corresponds to the converse operation, linking a selected workspace with all the workspaces which include it. And the "All inclusions" button corresponds to the operation of showing all inclusion relationships in this manner. In order to reduce viewer confusion, the links generated by the all doors and all inclusions operations are curved so that they do not overlap.

In addition to keyboard command buttons **540**, save button **108**, restore button **110** and augment button **112** invoke overview interface operations. The corresponding operations all relate to manipulation of a selected collection of workspaces. Because these operations relate to the more general topic of groups or suites of workspaces, we will treat them in the following section.

F. Suites of Workspaces

Generating a useful group or suite of workspaces involves a sufficient amount of effort that it is often worthwhile to preserve them. This requires not only that the windows or other display objects in the workspaces be preserved, but also that the placements, inclusions and other data in the workspaces's data structures be preserved so that the effort of recreating those workspaces is not necessary. For example, a user may wish to backup on a file server a suite of workspaces which has been created in a work session. Or a user who has created a useful suite of workspaces may store them on a file server for copying by other users. This may be especially useful for transferring a useful suite of workspaces from an expert to each of a group of novices. Once a suite of workspaces has been stored as a file, it can be mailed or copied like any other file.

Useful operations on suites of workspaces include the save, restore and augment operations invoked respectively by save button **108**, restore button **110** and augment button **112**. Although these buttons are presented in the overview and are thus a part of the overview interface mode, some of the operations they invoke when selected could be available at other times through appropriate user signals. The save operation, for example, stores a selected group of workspaces in a designated file, together with the necessary data to regenerate those workspaces and the display objects they contain. Therefore, the save operation is useful at any time that it is desirable to back up a suite of workspaces or to make a suite of workspaces available for mailing or copying. The restore and augment operations, on the other hand, take a suite of workspaces from such a file and regenerate and present the workspaces to a user, the restore operation replacing the user's preexisting workspaces and the augment operation adding the regenerated suite of workspaces to the preexisting workspaces.

These operations may be thought of as file operations because each involves storing data in a file or retrieving it from a file.

The data stored in or retrieved from a file by a file operation differs in one significant respect from the data in a workspace data structure: It includes not only the display characteristics from the underlying display system objects, but may also include data about the applications and other procedures which a display system object calls and the data structure a display system operates on in providing the contents of a window or other display object. This additional data may be necessary in order to recreate the display system object so that it can provide its display object within a recreated workspace. But the specific additional data which should be included in the file for a given display system object depends on the characteristics of the object. For some objects, no data should be stored, because the workspace system of any user who augments from the file will already contain an equivalent object, such as the user's mail facilities. In general, the context-dependent characteristics of the objects, including details like the user's name, should not be stored. For other objects, the entire display system object should be stored, because it is necessary for a task which the user will perform and the user's workspace system is unlikely to have an equivalent object. Indeed, a primary purpose of storing a suite of workspaces may be to provide a set of display system objects to an inexperienced user.

After discussing a window registration system which assists in obtaining the appropriate data from display system objects, we will discuss save, augment and restore operations which employ the window registration system.

1. Window Registration System. In order to obtain the appropriate data from each type of display system object, it is helpful to categorize the objects into types and provide a set of procedures for each type. For that purpose, one aspect of the present invention is to provide a window registration system, mentioned above in relation to providing window pictogram details which are similarly based on data from each type of display system object. This window registration system facilitates the process of retrieving data from display system objects by providing a set of functions appropriate for each of a number of types of display system object.

A window registration system is not necessary for the ordinary workspace operations described above because those operations involve data in the display system objects which are uniformly retrievable. In other words, the display system objects are structured so that the position, size, visibility (which may be collapsed into position), drop shadow data, shrinking data and other miscellaneous display characteristics are all retrievable by a procedure which is independent of which display system object is accessed. For example, this data could all be collected at the beginning of a data structure following the object's handle, so that it can be accessed and retrieved with the handle and without knowing the subsequent structure of the object. In fact, this is how conventional window systems are typically designed. But the window registration system is necessary to access and retrieve data from the subsequent part of the object because that part typically has a structure unique to that type of object.

FIG. **20** shows the relation between software components within a user interface system **570**, including window system **572**, user invoked file procedures **574** and window registration system **576**. Underlying window system **572** provides the actual user interface, receiving user signals and presenting display features to the user. When the signals from the user invoke one of the file procedures, such as save, restore or augment, window system **572** calls user invoked file procedures **574**, indicating which procedure is requested and providing any data necessary to that procedure's execution. During its execution, that procedure may require data from one of the display system objects in window system **572**. That data is retrieved by calling appropriate functions from window registration system **576**.

Window registration system **576** may be implemented in a number of ways. One implementation is a window type table containing a window type entry for each type of window. Each type entry includes a type handle or name which can be used to access that entry directly and a number of function handles which can be used to access the functions for that type. The display system object for each window of a given type responds to the same set of functions, so that the entry for that type can be set up by providing the type name and function handles for those functions.

The functions in the type table for each type may include, for example, a Recognize function, an Abstract function, a Recreate function and a Present function.

As discussed above in relation to box **516** in FIG. **19**, the Recognize function of a given type, when it receives the handle of a window, accesses the corresponding display system object in window system **572** to determine whether it is of that type. The Recognize function may do this by interrogating the object for a particular function or other property, such as whether the object allows application code to be run in a window. If the Recognize function recognizes the object, it returns the handle of its type to the procedure which called it, so that the procedure can then call other functions for that type. If the Recognize function does not recognize the object, it returns a response indicating non-recognition, such as a Boolean value of false.

The Abstract function of a given type provides an abstract description of a display system object which can be stored in a file. The Abstract function receives the handle of a display system object, accesses that object to obtain the data needed to recreate that object subsequently, and provides the data in an appropriate form, including the type name. The Abstract function could, for example, retrieve characteristics of the data presented within the window provided by that object or other results of the current execution of an application called by that object. As noted above, the Abstract function should not retrieve context-dependent data, because that data will be different when the display system object is set up in a different environment.

The Recreate function of a given type reconstitutes a display system object of that type from its handle and the abstract description provided by Abstract function. That abstract description may create the object from scratch or it may call applications and other procedures which are available in the user's environment to assist in recreating the object. It may not create a new object, but may rename an existing object or may obtain the handle of an existing object and provide that handle as the object's handle. The result is an object which fulfills a role in the workspace system.

The Present function of a given type, as mentioned in relation to box **518** in FIG. **19**, provides data used in presenting a window's pictogram in the overview. As shown in FIG. 5, a number of the window pictograms are labeled with words like "TEdit", "Exec" and "Snap". These words refer to applications called by the display system objects which provide those windows, and the Present function of the appropriate type accessed each such display system object to find the name of the application called. This is an example of the type of data the Present function may retrieve.

In general, window registration system 576 can handle as many functions as appropriate. The functions described above are illustrative of the kinds of functions which are useful. The type table provides rapid selection of the appropriate function.

The type table is created during initialization in box 220 in FIG. 12 and is, in effect, supported by an application in the display system that contains all the functions of all the recognized window types. This application, referred to as the window type registrar, also includes loading code which sets up the type table to include the type name and function handles for each of the recognized types. Furthermore, if a new type of display system object is added to the window system, its functions must also be written together with loading code for calling the window type registrar to add a new entry to the type table containing the new type's name and the handles of its functions.

The above-described window registration system is used primarily in relation to the save, restore and augment operations.

2. File Operations. Three file operations are provided in overview interface mode 212 by save button 108, restore button 110 and augment button 112. FIGS. 21A and 21B illustrate the save operation, while FIG. 22 illustrates the restore and augment operations.

The procedure in FIGS. 21A and 21B, which implements the save operation, begins in box 600 when a save command is received. The procedure prompts the user to select workspaces to be included in the saved file, in box 602. The test in box 604 determines whether the user selected any workspaces. If not, all the currently existing workspaces are selected in box 606. In either case, a list of the selected workspaces is generated in box 608 for subsequent operations. In box 610, the procedure prompts the user to provide a file name, and a file with that name is then set up in box 612.

At this point the procedure of FIGS. 21A and 21B begins to go through the list of workspaces generated in box 608. The test in box 614 determines whether any workspaces remain on the list. If so, the next workspace's data structure is accessed in box 616. The name or other handle of the workspace is written to the file being created locally in such a way that subsequent data items can be written behind it to complete a data structure depending from it. Then begins the process of writing that workspace's data structure to the file.

The test in box 620 determines whether that workspace's data structure has any remaining unexamined placements. If so, the next unexamined placement is accessed in box 622 and its handle is compared with the handles of placements on a list of placements whose corresponding display system objects have already been abstracted and written to the file, in box 624. If the handle is not yet on the handle list, it is added to the list in box 626.

The procedure then calls the Recognize function of each of the object types in the window registration system in turn. If any of the types recognizes the object, as determined in box 630, the Abstract function of that type is called in box 632 to obtain an abstracted description of the object from which it can be recreated. That description is then set to be the descriptor of the object, in box 634. If the object had not been recognized, the descriptor would be a code indicating that the object is of an unrecognized type and other appropriate data such as its title and other data from which it could be recreated if its type were registered, in box 636. In either case, a file handle to be used to access the descriptor in the file is generated and added to the handle list in a pair with the handle from the placement, in box 638. Then, the file handle is written to the file as a placement in the data structure of the workspace being examined, and a pair including the file handle and the descriptor is also written independently to the file, in box 640. Then the procedure returns to the test of box 620.

If the test in box 624 determines that the handle from the placement is already on the handle list, the corresponding file handle is retrieved from the handle list. That file handle is then written to the file as a placement in the data structure of the workspace being examined in box 642 before returning to the test of box 620.

When all of the placements in a workspace have been examined in this manner, the test in box 644 determines whether the workspace has any unexamined inclusions. If so, the next inclusion is accessed in box 646 and its handle is written to the file as an inclusion in the data structure of the workspace being examined in box 648 before returning to the test of box 644. When all the inclusions have been written in the manner, the procedure returns to the test of box 614.

When the test in box 614 determines that all the workspaces on the list have been examined, the file is complete. The completed file is then stored, in box 650. The procedure of FIGS. 21A and 21B could also be structured to create an entire list of handles with descriptors without writing any data to the file. In that case, the file would be first constructed to include the handle/descriptor pairs, after which the procedure would scan through the workspace list to write out each workspace's name, followed by its placements and inclusions. In either case, when the file is stored in a file server or other appropriate location, it can be copied, mailed or otherwise accessed for subsequent operations.

As can be seen from the procedure of FIGS. 21A and 21B, none of the references to display system objects is permitted to dangle. In other words, every handle which is found in any of the placements in the selected workspaces results in the writing of a file handle/descriptor pair to the file. But any inclusion with a handle of a workspace which is not selected is permitted to dangle, meaning that the procedure makes no effort to add the included workspace to those selected or to change its handle to the handle of a selected workspace.

FIG. 22 illustrates procedures implementing the restore and augment operations which basically reverse the process in FIGS. 21A and 21B. The procedures of FIG. 22 begin in box 640 when a restore or augment command is received. The procedure prompts the user for the name of the file to be restored or augmented in box 642, and that file is retrieved in box 644. The file handle/descriptor pairs stored in it are used to recreate the corresponding display system objects by calling the appropriate Recreate functions in box 646. The descriptor includes, in each case, the type of the object, and that type's Recreate function can be called to recreate the object. It may do so by setting up any necessary applications and by taking other steps. But if the type is unrecognized, a default Recreate function is called to create an object of unregistered type. That object retains any other data included in the descriptor, and if that object's type is later added to the window registration system that object can be recreated.

As each object is recreated in box **646**, it receives a display system handle, and that handle is used to create a list of pairs, each including a display system handle and a file handle, in box **648**. This list is then used to change all the file handles in the workspace data structure to display system handles, in box **650**. This step can be performed as the workspace data structures are retrieved from the file, so that when it is completed the workspace data structures have all been retrieved. At this point the inclusions may have dangling references, as noted above, if there were dangling references in the file.

The next step which is taken depends on whether the command was to restore or to augment, as shown by the branch in box **652**. If the command was to restore, the preexisting workspaces are deleted in box **654** and the overall data structure from the file becomes the overall workspaces data structure. The procedure exits and reenters the overview in box **656** so that the overview display can be recreated and stored in the overview cache. Then the procedure reenters the overview interface mode in box **658**.

If the command was to augment, the test in box **660** determines whether any of the workspace data structures from the file remain to be examined. If so, the next workspace data structure is accessed in box **662**. Its name is compared with the names of preexisting workspaces in box **664**, and if it is a duplicate, a new name is assigned to the workspace data structure from the file, in box **666**. Finally, the workspace data structure is added to the preexisting overall workspaces data structure in box **668**. When all the workspaces from the file have been added to the preexisting overall workspaces data structure, the procedure exits and reenters the overview in box **670** so that the overview display can be recreated and stored in the overview cache. Then the procedure reenters the overview interface mode in box **672**.

The usefulness of the operations described in relation to FIGS. **21A**, **21B**, and **22** can be better understood by considering the specific problems of how to set up workspaces for an inexperienced or naive user; how to enable a user to configure a suite of workspaces; and how to deliver applications within workspaces. An experienced or expert user creates a set of workspaces which includes a number of workspaces with windows appropriate for delivery. The application behind each window need not contain extensive data, since the function of the workspaces is to provide a blueprint or empty suite of workspaces including applications which a subsequent user will fill in with appropriate data. The expert then invokes a save operation on those workspaces, storing them as a suite of workspaces in a file on a file server. The recipient user, whether an inexperienced user or any other user receiving the saved suite of workspaces, then accesses the file server and invokes an augment operation on the file, causing the suite of workspaces to be added to the preexisting workspaces.

We turn now to a useful technique for delivering a suite of workspaces.

3. Catalogue. Delivery of a suite of workspaces may be implemented using a catalogue metaphor, as illustrated in FIGS. **23** and **24**. In order to make the catalogue available to the user, a catalogue workspace is provided which includes a display object like catalogue cover **680** shown in FIG. **23**. This catalogue workspace could, for example, be the initial workspace created during system setup as described in relation to FIG. **11**, so that catalogue cover **680** would be presented to the user at the beginning of display system operation. Catalogue cover **680** bears the term "ROOMS" which, as noted above, is a trademark of Xerox Corporation used in connection with an implementation of the invention.

Catalogue cover **680** may be implemented as a window which includes a basic piece of bit map, together with a number of buttons attached to the basic bit map. As used here, the term "button" means a piece of bit map which can be positioned at the edge of or at a point within a larger piece of bit map and which, when selected by the user, results in the execution of an associated piece of software. The buttons attached to catalogue cover **680** are shown as tabs at the right side of FIG. **23**, including introduction tab **682**, suites tab **684**, ROOMS tab **686** and decor tab **688**. Each of these tabs, when selected, results in the execution of a corresponding routine.

FIG. **24** illustrates the result of selecting suites tab **684**. Catalogue cover **680** is removed from the display and replaced by suites pages **690**, another basic piece of bit map. Tabs **692**, **694**, **696** and **698** are buttons attached to suites pages **690** and correspond in function to tabs **682–288** in FIG. **23**. Box **702** is also a button positioned within suites pages **690**, and selecting it results in an augment operation which adds a suite of workspaces called Office—**1** to the preexisting workspaces. At the conclusion of such an operation, the windows within the selected suite of workspaces will be opened and the workspaces will all be accessible. Suites pages **690** includes a piece of bit map **704** from one of the workspaces in Office—**1**, to suggest the tasks for which that suite of workspaces is useful. Similarly, Box **706** is a button within suites pages **690**, and selecting it results in an augment operation adding a suite of workspaces called Techdesk, represented by a piece of bit map **708** from one of its workspaces.

Selecting introduction tab **682** or **692** results in introduction pages which explain to the user how to make use of the options presented within the catalogue metaphor. Selecting ROOMS tab **686** or **696** results in workspaces pages within which buttons are presented which when selected, augment a single workspace rather than a suite of workspaces. Selecting decor tab **688** or **698** results in decor pages within which buttons are presented which the user can select to modify the background pattern of a selected workspace. To further follow the catalogue metaphor, additional buttons with a piece of bit map which looks like a page corner can be used to permit page turning within each section of the catalogue.

The catalogue metaphor proves particularly useful as a technique for delivering applications in a system running workspaces, because of the augment operation. But it could be applied in other systems as well. One general feature of the catalogue metaphor which makes it useful is the uniform access it provides to all variations possible within the retrieved applications, including backgrounds and other display characteristics of the workspaces and the various suites of workspaces which are available.

In order to reach the catalogue, it may be appropriate for the user to go through preliminary steps, since not all users will want the catalogue. When the workspace system enters the initial workspace, a menu may be available to set up workspaces directly or to create doors to enter the catalogue or other special workspaces which assist a new user in understanding multiple workspaces.

We turn now to consider other characteristics of different implementations of the invention.

G. Implementations of Multiple Virtual Workspaces

The invention has been implemented in two distinct systems. One is called "Desk Tops" and the other, as noted above, is called "ROOMS".

Desk Tops is implemented in the Cedar environment developed at the Palo Alto Research Center of Xerox Corporation. Desk Tops creates several virtual desktops, each of which appears to be a normal desktop when it is displayed. Desk Tops makes use of viewers, which are containers which resemble windows. A desktop is a special viewer which can contain a configuration of viewers, the viewers in a desktop being typically tiled in two columns on the screen.

Desk Tops provided for multiple desktops and commands for moving back and forth between desktops. Facilities are also available for moving and copying viewers between desktops and for placing viewers in iconic form. A particular viewer can be in more than one desktop, and it can have a different size and position in each desktop. The data structure for each desktop contains a placement in the form of a pointer to each contained viewer and the size and position of that viewer in that desktop. When the user switches between desktops, the current configuration of viewers is saved in the current desktop before moving the viewers in the new desktop onto the screen.

Desk Tops is implemented so that a number of functions relating to a given type of viewer are called using a registration system resembling the window registration system described above. In addition, a viewer is made invisible by resetting a boolean value in the display system object which provides it. Also, whenever a program prints to a viewer that is not on the screen, Desk Tops moves that viewer to the current desktop before printing to it, so that the user will be able to see what is printed.

Desk Tops does not have an overview, but if a user deletes a desktop which contains a viewer which is not on any other desktop, that viewer is moved onto the current desktop in iconic form so that it will not be stranded.

Deleting a viewer may result in deletion of that viewer in all the desktops containing it, but not in deletion of the placements.

ROOMS is implemented in the version of Lisp marketed under the trademark Interlisp-D by Xerox Corporation. Interlisp-D has a number of unusual characteristics which affect the manner in which ROOMS is implemented. For example, all of the display objects in Interlisp-D are windows, with an icon being a special type of shrunken window; the underlying display system object remains active even in iconic form. The various windows in Interlisp-D can overlap freely, but a user selection in a given window will bring that window to the top of the display stack, through a default procedure.

Another characteristic of Interlisp-D windows is that a group of them can be attached so that they will be treated as a single display object. In that case, one of the windows controls the entire group, so that the controlling window becomes the window whose handle is used in the placement for that group. When the group is shrunk, it creates a single shrunken icon, which is a new window, so that the group of windows becomes invisible. Even then, however, the controlling window remains the window of interest. When performing workspace operations involving such a group, it is necessary to include in the placement data about whether shrunk, the size of the shrunken form, drop shadow and so forth, but it is not necessary to include the list of attached windows in the placement.

In Interlisp-D, it is possible to lock a window to a particular location on the screen. On the other hand, the only practical way to make a window invisible is to cause its display system object, also called a window, to provide its output to an invisible location, like the hiding place described above. In order to move a locked window to the hiding place, it is necessary to override the lock until the window is moved and then relock it.

ROOMS includes the overview, catalogue, sharing of display system objects, inclusions of workspaces and other features described in the preceding sections.

These two implementations each apply the invention to a preexisting display system. An implementation of the invention with such a display system may require minor modifications to fit the particular features of the display system. But the invention should be applicable to the conventional display systems now available.

H. Miscellaneous

Many other modifications, variations and extensions of the invention will be apparent to those skilled in the art from the above description. In many areas, a number of options are available for implementing a given feature, and the choice of an implementation depends on specific design factors.

As described above, a number of different sequences of user signals can lead to a workspace exit procedure. The background menu can be particularly important when in a workspace because it always permits the user to enter another workspace or the overview, so that the user can never be trapped in a workspace and unable to leave. In the overview, however, the background menu could be suppressed throughout the overview or within each workspace pictogram, because other steps can always be taken to leave the overview, such as using the enter operation to enter a workspace.

Another technique which protects the user from getting trapped is the back door. A back door can be automatically created whenever the user exits one workspace and enters another, either directly or through the overview. No back door would ordinarily be created, however, if the user reenters a workspace from itself. The workspace exit and entry procedures will determine whether to create a back door and, if so, where to locate it, according to any appropriate protocol.

Like other doors, the back door is a display object which, when selected, results in a switch out of the currently displayed workspace and into another workspace. A door is usually labelled with the name of the workspace to which it leads, and a display object analogous to a door could also be provided for entering the overview.

The background specifications in the workspace data structures can include various commands resulting in a distinctive appearance for each workspace. The whole background or a region can be shaded or tesellated. A frame can be created around a region with a specified width. A piece of bitmap or a string of text can be located within the background. As described above, background commands can be made conditional, as on whether the workspace is included in another workspace in the current display.

The overview also presents rich possibilities for variation. The operations available in the overview interface mode may be extended to include any convenient operation which assists the user in the use of the system, whether related to navigation or to another purpose.

An important potential extension of the invention is the sharing of a workspace by two or more users. This sharing could be done in a number of ways. Serial sharing could be provided by storing the workspace on a shared file server with a lock which the user would set when using the workspace and unlock when leaving the workspace. The user could use the save operation in the process of leaving the workspace to preserve the current state of the display objects. Simultaneous sharing could also be provided with a shared file server or with a remote procedure call. Simultaneous sharing of a workspace could be implemented by sharing all the windows in a workspace, along the lines of a multi-user interface, or by sharing the workspace itself.

Although the invention has been described in relation to various implementations, together with modifications, variations and extensions thereof, other implementations, modifications, variations and extensions are within the scope of the invention. The invention is therefore not limited by the description contained herein or by the drawings, but only by the claims.

What is claimed:

1. A system comprising:

a display;

first and second workspace data structures relating respectively to first and second workspaces that can be presented on the display; each of the first and second workspaces including a respective set of display objects; each of the display objects being perceptible as a distinct, coherent set of display features; the display objects of each respective set being perceptible as having spatial positions relative to each other when the respective workspace is presented on the display;

display object means for generating first and second display objects; the first workspace data structure being linked to the display object means so that the first display object is in the respective set of display objects of the first workspace; the second workspace data structure being linked to the display object means so that the second display object is in the respective set of display objects of the second workspace; and

control means for accessing the first workspace data structure to cause the display to present the first workspace including the first display object; the control means further being for accessing the second workspace data structure to cause the display to present the second workspace including the second display object; the display object means generating the first and second display objects so that the second display object is perceptible as the same tool as the first display object when the second workspace is presented after the first workspace.

2. The system of claim **1**, further comprising a first linking data structure linking the first workspace data structure to the display object means and a second linking data structure linking the second workspace data structure to the display object means; the control means further being for accessing the first linking data structure after accessing the first workspace data structure to cause the display to present the first workspace including the first display object; the control means further being for accessing the second linking data structure after accessing the second workspace data structure to cause the display to present the second workspace including the second display object.

3. The system of claim **2** in which the first linking data structure includes first display characteristic data indicating a respective display characteristic of the first display object and the second linking data structure includes second display characteristic data indicating a respective display characteristic of the second display object, the control means further being for accessing the first display characteristic data while accessing the first linking data structure to cause the display to present the first display object with its respective display characteristic; the control means further being for accessing the second display characteristic data while accessing the second linking data structure to cause the display to present the second display object with its respective display characteristic.

4. The system of claim **3** in which the respective display characteristics of the first and second display objects are respective positions, the first and second display characteristic data indicating the respective positions of the first and second display objects, respectively.

5. The system of claim **3** in which the respective display characteristics of the first and second display objects are respective sizes, the first and second display characteristic data indicating the respective sizes of the first and second display objects, respectively.

6. The system of claim **2** in which the control means is further for accessing the display object means with a unique identifier identifying the display object means, the first and second linking data structures each including the unique identifier.

7. The system of claim **1**, further comprising a first linking data structure linking the first workspace data structure to the display object means and a second linking data structure linking the second workspace data structure to the first workspace data structure so that the second workspace data structure is linked to the display object means through the first workspace data structure; the control means further being for accessing the first linking data structure after accessing the first workspace data structure to cause the display to present the first workspace including the first display object; the control means further being for accessing the second linking data structure after accessing the second workspace data structure to cause the display to present the second workspace including the second display object.

8. The system of claim **1** in which the display object means generates the first and second display objects with shared features so that the first and second display objects are perceptible as the same display object.

9. The system of claim **1** in which the first and second display objects each contain a respective plurality of internal display objects that are perceptible as having relative positions within a respective part of an internal space; the first display object's respective part of the internal space having a first location in the internal space and the second display object's respective part of the internal space having a second location in the internal space; the display object means providing the first and second display objects with the first and second locations being the same so that the second display object appears to the user to be the same tool as the first display object when the second workspace is presented after the first workspace.

10. The system of claim 9 in which the first and second display objects are windows and the internal display objects are characters in a text.

11. The system of claim 1, further comprising input means for receiving signals from a user; the signals from the user including a first signal requesting an operation affecting the first display object and a second signal requesting an operation affecting the second display object; the display object means further being for receiving the first and second signals from the input means; the display object means responding to the first signal by generating a first response, the display object means further responding to the second signal by generating a second response, the display object means further generating the first and second responses so that the second display object is perceptible as the same tool as the first display object when the second workspace is presented after the first workspace.

12. The system of claim 1, further comprising input means for receiving signals from a user; the first display object containing a user selectable display feature; the signals from the user including a signal selecting the user selectable display feature and requesting an operation; the display object means further being for receiving and responding to the signal selecting the user selectable display feature by performing the requested operation; after performing the requested operation, the display object means generating the first and second display objects differently than before receiving the signal such that the second display object is perceptible as the same tool as the first display object when the second workspace is presented after the first workspace.

13. The system of claim 1, further comprising input means for receiving signals from a user, the signals from the user including a signal requesting a switch from the first workspace to the second workspace; the control means further being for responding to the signal requesting a switch from the first workspace to the second workspace by causing the display to cease presenting the first workspace and to begin presenting the second workspace.

14. The system of claim 13 in which the first workspace's respective set of display objects further includes a selectable workspace switch display object; the system further comprising, in addition to the first above-mentioned display object means, a second display object means for generating the workspace switch display object, the first workspace data structure being linked to the second display object means; the control means further being for accessing the first workspace data structure to cause the display to present the first workspace including the workspace switch display object; the signal requesting the switch being a signal selecting the workspace switch display object.

15. The system of claim 13, further comprising a workspace return display object means for generating a selectable workspace return display object, the control means further responding to the switch sequence by linking the workspace return display object means to the second workspace data structure, the second workspace's respective set of display objects including the workspace return display object after the second workspace data structure is linked to the workspace return display object means; the control means further being for accessing the second workspace data structure to cause the display to present the second workspace including the workspace return display object; the signals from the user further including a signal selecting the workspace return display object; the control means further being for responding to the signal selecting the workspace return display object by causing the display to cease presenting the second workspace and to begin presenting the first workspace.

16. The system of claim 13 in which the display object means maintains a continuous state while the control means causes the display to cease presenting the first workspace and to begin presenting the second workspace.

17. The system of claim 13 in which the input means comprises a mouse.

18. The system of claim 1 in which the display has a display area, each workspace occupying the entire display area when it is presented.

19. The system of claim 1 in which the first workspace's respective set of display objects further includes a third display object, the system further comprising, in addition to the first above-mentioned display object means, a second display object means for generating the third display object, the first workspace data structure being linked to the second display object means so that the third display object is one of the respective set of display objects of the first workspace; the control means further being for accessing the first workspace data structure to cause the display to present the first workspace including the third display object; the second workspace's respective set of display objects not including a display object that is perceptible as the same tool as the third display object.

20. The system of claim 1 in which the first workspace's respective set of display objects further includes a third display object and the second workspace's respective set of display objects further includes a fourth display object, the system further comprising, in addition to the first above-mentioned display object means, a second display object means for generating the third and fourth display objects; the first workspace data structure being linked to the second display object means so that the third display object is one of the respective set of display objects of the first workspace; the second workspace data structure being linked to the second display object means so that the fourth display object is one of the respective set of display objects of the second workspace; the control means further being for accessing the first workspace data structure to cause the display to present the first workspace including the third display object and for accessing the second workspace data structure to cause the display to present the second workspace including the fourth display object; the fourth display object being perceptible as the same tool as the third display object when the second workspace is presented after the first workspace.

21. A method of operating a system that includes:

a display;

input means for receiving signals from a user;

display object means for generating a plurality of display objects; each of the display objects being perceptible as a distinct, coherent set of display features;

the method comprising the steps of:

causing the display to present a first set of the display objects, the display objects of the first set being perceptible as having spatial positions relative to each other when presented on the display; the first set of display objects including a switching display object and a first tool display object;

while the first set of display objects is being presented, receiving a switch request signal from the input means, the switch request signal indicating selection of the switching display object; and

responding to the switch request signal by causing the display to cease presenting the first set of display objects and to begin presenting a second set of the display objects, the display objects of the second set being perceptible as having spatial positions relative to each other when presented on the display; the second set of display objects including a second tool display object, the first and second tool display objects being perceptible as the same tool.

22. The method of claim **21** in which the switching display object has a type, the type indicating whether it is necessary to include in the second set of display objects a return switching display object for switching back to the first set of display objects, the display object means further being for generating the return switching display object, the step of responding to the switch request signal comprising the substep of including the return switching display object in the second set of display objects if the type of the switching display object indicates that it is necessary to do so.

23. The method of claim **22**, further comprising the steps of:

while the second set of display objects are being presented, receiving from the input means the return switch request signal; and

responding to the switch request signal by causing the display to cease presenting the second set of display objects and to begin presenting the first set of display objects.

24. A method of operating a system that includes:

a display;

input means for receiving signals from a user;

first and second workspace data structures relating respectively to first and second workspaces that can be presented on the display; each of the first and second workspaces including a respective set of display objects; each of the display objects being perceptible as a distinct, coherent set of display features; the display objects of each respective set being perceptible as having spatial positions relative to each other when the respective workspace is presented on the display; and

display object means for generating first and second display objects; the first workspace data structure being linked to the display object means so that the first display object is in the respective set of display objects of the first workspace; the second workspace data structure being linked to the display object means so that the second display object is in the respective set of display objects of the second workspace;

the method comprising the steps of:

causing the display to present the first workspace, the step of causing the display to present the first workspace comprising the substep of accessing the first workspace data structure so that the first workspace includes the first display object generated by the display object means;

receiving a switch signal from the input means while the first workspace is being presented, the switch signal requesting a switch from the first workspace to the second workspace;

responding to the switch signal by causing the display to cease presenting the first workspace and to begin presenting the second workspace, the step of responding to the switch signal comprising the substep of accessing the second workspace data structure so that the second workspace includes the second display object; the display object means generating the first and second display objects so that the second display object is perceptible as the same tool as the first display object.

25. The method of claim **24** in which the system further includes a linking data structure linking the second workspace data structure to the display object means; the step of responding to the switch signal comprising, after the substep of accessing the second workspace data structure, the further substep of accessing the linking data structure.

26. The method of claim **25** in which the linking data structure includes a unique identifier identifying the display object means, the step of responding to the switch signal comprising, after the substep of accessing the linking data structure, the further substep of accessing the display object means with the unique identifier so that the display object means generates the second display object.

27. The method of claim **25** in which the linking data structure includes display characteristic data indicating a display characteristic of the second display object, the step of responding to the switch signal comprising, after the substep of accessing the linking data structure, the further substep of accessing the display object means with the display characteristic data so that the display object means generates the second display object with the indicated display characteristic in the second workspace.

28. The method of claim **24** in which the step of responding to the switch signal comprises the substep of maintaining the display object means in a continuous state.

29. The method of claim **24** in which the step of responding to the switch signal comprises the substep of causing the display object means to cease generating the first display object and to begin to generate the second display object.

30. The method of claim **29** in which the substep of causing the display object means to cease generating the first display object and to begin to generate the second display object comprises the substeps of:

causing the display object means to change from generating the first display object to generating an invisible display object; and

causing the display object means to change from generating the invisible display object to generating the second display object.

31. The method of claim **30** in which the substep of causing the display object means to change from generating the first display object to generating an invisible display object comprises the substep of causing the display object means to generate the invisible display object at a different location than the first display object, the different location not being presented on the display.

32. The method of claim 24 in which the system further includes a first linking data structure linking the first workspace data structure to the display object means and a second linking data structure linking the second workspace data structure to the first workspace data structure so that the second workspace data structure is linked to the display object means through the first workspace data structure; the step of responding to the switch signal comprising, after the substep of accessing the second workspace data structure, the further substeps of:

accessing the second linking data structure;

accessing the first workspace data structure after the substep of accessing the second linking data structure; and

accessing the first linking data structure after accessing the first workspace data structure to cause the display to present the second display object.

33. The method of claim 24, comprising the further steps of:

while the display is presenting the second workspace, receiving a return signal from the input means, the return signal requesting a switch back from the second workspace to the first workspace; and

responding to the return signal by causing the display to cease presenting the second workspace and to begin presenting a redisplayed form of the first workspace.

34. The method of claim 33 in which the step of responding to the switch signal comprises the substep of storing display organization data indicating the organization of the first workspace and the step of responding to the return signal comprises the substep of organizing the redisplayed form of the first workspace according to the display organization data.

35. The method of claim 34 in which the substep of storing display organization data comprises storing display organization data in a linking data structure linking the first workspace data structure and the display object means, the organizing substep comprising accessing the linking data structure to retrieve the display organization data.

36. The method of claim 33, further comprising the step of continuing operation of the display object means from the presentation of the first wordspace through the presentation of the redisplayed form of the first workspace so that the first display object in the redisplayed form of the first workspace is generated by display object means operations which continue from those which generated the first display object in the presentation of the first workspace.

37. The method of claim 24 in which the step of responding to the switch signal comprises the substep of causing the display to cease presenting the first workspace and to begin presenting the second workspace rapidly enought that the user perceives a change of location from the first display object to the second display object.

38. A system comprising:

a display;

display object means for generating a plurality of display objects, each of the display objects being perceptible as a distinct, coherent set of display features when presented on the display; the plurality of display objects including first and second display objects;

first and second workspace data structures relating respectively to first and second workspaces that can be presented on the display; each of the first and second workspaces including a respective set of the display objects; the display objects of each respective set being perceptible as having spatial positions relative to each other when the respective workspace is presented on the display;

first and second linking data structures; the first linking data structure linking the first workspace data structure to the display object means so that the first display object is one of the respective set of display objects of the first workspace; the second linking data structure linking the second workspace data structure to the display object means so that the second display object is one of the respective set of display objects of the second workspace; the display object means generating the first and second display objects so that the first and second display objects are perceptible as the same tool; and

control means for accessing the first workspace data structure and the first linking data structure to cause the display object means to generate the first display object when the first workspace is presented and for accessing the second workspace data structure and the second linking data structure to cause the display object means to generate the second display object when the second workspace is presented.

39. The system of claim 38 in which the first linking data structure includes first display characteristic data indicating a respective display characteristic of the first display object and the second linking data structure includes second display characteristic data indicating a respective display characteristic of the second display object, the control means further being for accessing the first display characteristic data while accessing the first linking data structure to cause the display to present the first display object with its respective display characteristic; the control means further being for accessing the second display characteristic data while accessing the second linking data structure to cause the display to present the second display object with its respective display characteristic.

40. The system of claim 39 in which the respective display characteristics of the first and second display objects are respective positions, the first and second display characteristic data indicating the respective positions of the first and second display objects, respectively.

41. The system of claim 39 in which the respective display characteristics of the first and second display objects are respective sizes, the first and second display characteristic data indicating the respective sizes of the first and second display objects, respectively.

42. The system of claim 38 in which the control means is further for accessing the display object means with a unique identifier identifying the display object means, the first and second linking data structures each including the unique identifier.

43. The system of claim 38, further comprising input means for receiving signals from a user, the signals from the user including a request for a display system operation and a request for a workspace transition; the display object means further being for responding to the request for the display system operation and the control means further being for responding to the request for the workspace transition.

44. A method of operating a system that includes:

a display;

display object means for generating a plurality of display objects, each of the display objects being perceptible as a distinct, coherent set of display features when presented on the display; the plurality of display objects including first and second display objects;

first and second workspace data structures relating respectively to first and second workspaces that can be presented on the display; each of the first and second workspaces including a respective set of the display objects; the display objects of each respective set being perceptible as having spatial positions relative to each other when the respective workspace is presented on the display; and

first and second linking data structures; the first linking data structure linking the first workspace data structure to the display object means so that the first display object is one of the respective set of display objects of the first workspace; the second linking data structure linking the second workspace data structure to the display object means so that the second display object is one of the respective set of display objects of the second workspace; the display object means generating the first and second display objects so that the first and second display objects are perceptible as the same tool;

the method comprising the steps of:

accessing the first workspace data structure and the first linking data structure to cause the display object means to generate the first display object when presentation of the first workspace begins; and

accessing the second workspace data structure and the second linking data structure to cause the display object means to generate the second display object when presentation of the second workspace begins.

45. The method of claim **44** in which the first linking data structure includes first display characteristic data indicating a respective display characteristic of the first display object and the second linking data structure includes second display characteristic data indicating a respective display characteristic of the second display object; the step of accessing the first workspace data structure and the first linking data structure comprising the substep of accessing the display object means with the first display characteristic data to cause the display to present the first display object with its respective display characteristic; the step of accessing the second workspace data structure and the second linking data structure comprising accessing the display object means with the second display characteristic data to cause the display to present the second display object with its respective display characteristic.

46. The method of claim **44** in which the first and second linking data structures each includes a unique identifier identifying the display object means; the step of accessing the first workspace data structure and the first linking data structure comprising accessing the display object means with the unique identifier so that the display object means generates the first display object; the step of accessing the second workspace data structure and the second linking data structure comprising accessing the display object means with the unique identifier so that the display object means generates the second display object.

47. The method of claim **44** in which the system further includes input means for receiving signals from a user; the method further comprising the steps of:

while the first workspace is being presented, receiving from the input means a request for transition from the first workspace to the second workspace; and

responding to the request by causing the display to cease presenting the first workspace and to begin presenting the second workspace, the step of responding to the request including the step of accessing the second workspace data structure and the second linking data structure.

48. The method of claim **47** in which the signals from the user further include a request for a return transition from the second workspace to the first workspace; the method further comprising the steps of:

while the second workspace is being presented, receiving from the input means a request for a return transition from the second workspace to the first workspace; and

responding to the request by causing the display to cease presenting the second workspace and to begin presenting the first workspace, the step of responding to the request including the step of accessing the first workspace data structure and the first linking data structure.

49. A system comprising:

a display;

input means for receiving signals from a user;

display object means for generating a plurality of display objects; each of the display objects being perceptible as a distinct, coherent set of display features; and

control means for causing the display to present a first set of the display objects, the display objects of the first set being perceptible as having spatial positions relative to each other when presented on the display; the first set of display objects including a switching display object and a first tool display object; the signals from the user including a switch request signal indicating selection of the switching display object; the control means further being for receiving the switch request signal from the input means; the control means further being for responding to the switch request signal by causing the display to cease presenting the first set of display objects and to begin presenting a second set of the display objects, the display objects of the second set being perceptible as having spatial positions relative to each other when presented on the display; the second set of display objects including a second tool display object, the first and second tool display objects being perceptible as the same tool.

50. The system of claim **49** in which the switching display object is not location sensitive.

51. The system of claim **50** in which the switching display object is an icon.

52. The system of claim **50** in which the switching display object is perceptible as a miniature door.

53. A method of operating a system that includes:

a display;

input means for receiving signals from a user;

display object means for generating a plurality of display objects; each of the display objects being perceptible as a distinct, coherent set of display features;

first and second workspace data structures relating respectively to first and second workspaces that can be presented on the display; each of the first and second workspaces including a respective set of the display objects; the display objects of each respective set being perceptible as having spatial positions relative to each other when the respective workspace is presented on the display; and the first workspace data structure being linked to the display object means so that a first one of the display objects is in the respective set of display objects of the first workspace;

the method comprising the steps of:

causing the display to present the first workspace, the step of causing the display to present the first workspace comprising the substep of accessing the first workspace data structure so that the first workspace includes the first display object generated by the display object means;

while presenting the first workspace, receiving from the input means a switch signal requesting a switch from the first workspace to the second workspace and requesting a transfer of the first display object between the first workspace and the second workspace; and

responding to the switch signal by causing the display to cease presenting the first workspace and to begin presenting the second workspace, the step of responding to the switch signal comprising the substeps of linking the second workspace data structure to the display object means so that a second one of the display objects is in the respective set of display objects of the second workspace and then accessing the second workspace data structure so that the second workspace includes the second display object; the display object means generating the first and second display objects so that the second display object appears to be the same tool as the first display object.

54. The method of claim **53** in which the transfer is a move operation.

55. The method of claim **53** in which the transfer is a copy operation.

56. A system comprising:

a display;

input means for receiving signals from a user;

display object means for generating a plurality of display objects; each of the display objects being perceptible as a distinct, coherent set of display features; and

control means for causing the display to present a first set of the display objects, the display objects of the first set being perceptible as having spatial positions relative to each other when presented on the display; the first set of display objects including a first tool display object; the signals that can be received by the input means including a switch request signal requesting a switch from the first set of display objects to a second set of display objects; the control means further being for responding to the switch request signal by causing the display to cease presenting the first set of display objects and to begin presenting a second set of the display objects, the display objects of the second set being perceptible as having spatial positions relative to each other when presented on the display; the second set of display objects including a second tool display object, the first and second tool display objects being perceptible as the same tool; the control means further being for responding to the switch request signal by storing data indicating display characteristics of the first display object before causing the display to cease presenting the first set of display objects.

57. The system of claim **56** in which the data indicating display characteristics of the first display object is data indicating the position of the first display object.

58. The system of claim **57** in which the data indicating display characteristics of the first display object is data indicating the size of the first display object.

59. A method of operating a system that includes:

a display;

input means for receiving signals from a user;

display object means for generating a plurality of display objects; each of the display objects being perceptible as a distinct, coherent set of display features;

the method comprising the steps of:

causing the display to present a first set of the display objects, the display objects of the first set being perceptible as having spatial positions relative to each other when presented on the display; the first set of display objects including a first tool display object;

while presenting the first set of the display objects, receiving from the input means a switch request signal requesting a switch from the first set of display objects to a second set of display objects; and

responding to the switch request signal by causing the display to cease presenting the first set of display objects and to begin presenting the second set of the display objects, the display objects of the second set being perceptible as having spatial positions relative to each other when presented on the display; the second set of display objects including a second tool display object, the first and second tool display objects being perceptible as the same tool; the step of responding to the switch request signal comprising the substep of storing data indicating display characteristics of the first display object before causing the display to cease presenting the first set of display objects.

60. The method of claim **59**, further comprising the steps of:

while the second set of display objects is being presented, receiving from the input means a return switch request signal requesting a switch back from the second set of display objects to the first set of display objects; and

responding to the return switch request signal by causing the display to cease presenting the second set of display objects and to being presenting the first set of display objects; the step of responding to the return switch request signal comprising the substep of accessing the stored data indicating display characteristics of the first display object and presenting the first display object in the first workspace with the indicated display characteristics.

61. The method of claim **59** in which the step of responding to the switch request signal comprises the substep of accessing the stored data indicating display characteristics of the first display object and presenting the second display object in the second workspace with the indicated display characteristics.

62. The method of claim **59**, further comprising the steps of:

while the first set of display objects is presented, receiving from the input means a display object change signal requesting a change in the display characteristics of the first display object; and

responding to the display object change signal by

presenting the first display object with its display characteristics changed as requested;

the substep of storing data indicating display characteristics comprising storing data indicating the changed display characteristics of the first display object.

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